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The Use of Bags for Solid Waste Storage and Collection

Stone and Company, Inc.

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The study was conducted to evaluate the suitability of disposable plastic and paper sack materials for use as solid waste containers. Six residential areas in Inglewood, California, were selected; three were to receive bags for test use and the remainder to serve as a control. Bag systems studied included household polyethylene and paper bags on holders, free-standing paper bags and polyethylene can liners as well as large polyethylene commercial bin liners that were distributed to a number of restaurants, in the city. Results were obtained by using time and motion studies and this information was reinforced by laboratory testing and by an aggressive questionnaire program. A model of the collection system was then developed and subsequent simulation studies were employed for cost analysis. The project demonstrated that bags are quite satisfactory as solid waste container replacements for cans. Sanitation, collection system productivity and efficiency, and neighborhood appearance were improved and the participants indicated positive acceptance of the bags. The most prominent problems, however, were the difficulties in developing efficient bulk storage and distribution methods of the bags.

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This final report (SW-42d) on work performed under
solid waste management demonstration grant no. G06-EC-00172
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RALPH STONE AND COMPANY, INC., ENGINEERS
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U.S. ENVIRONMENTAL PROTECTION AGENCY

1972

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Our appreciation to the bag manufacturing companies and their representatives and to the cities providing background information on their experiences with bags is gratefully acknowledged.

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*Now the Office of Solid Waste Management Programs, U.S. Environmental Protection Agency.

ABSTRACT

A two-year demonstration study of bags for use as solid waste containers was performed in the City of Inglewood, California. Bag systems studied included household polyethylene and paper bags on holders, free-standing paper bags and polyethylene can liners as well as large polyethylene commercial bin liners. A nationwide municipal questionnaire survey of bag use completed by the project engineer is also included in this report.

Three residential areas, each consisting of a demonstration bag route and a conventional can control route, were studied for six months and four householder questionnaires were distributed. The bag and liner systems were evaluated with respect to cans and to each other in each area and in a residential condominium. A bin liner questionnaire was distributed to commercial restaurant establishments.

The local transfer station and sanitary landfill operations were observed and bag materials tests together with studies on litter, dust, bacteria, flies, accidents, and noise related to bags and cans as waste containers were made.

A mathematical simulation model and benefit-cost analyses were run to compare waste collection system operations for bags and cans.

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SUMMARY

A. Background

1. Demonstration Location. The City of Inglewood is located in populous Los Angeles County in Southern California and in 1968 had a population of about 94,000 persons, and an estimated 36,000 dwelling units with an average occupancy rate of 2.6 persons per unit.

In 1957, the City established a residential solid waste collection service utilizing two-man municipal crews and equipment for once-a-week curbside collection of combined solid waste, less garbage. In 1961, the City experimented with one-man collection crews, and in 1963, following an increase in the size of their collection equipment from 20- to 35-cu yd capacity, one-man operation was implemented.

2. Objectives. The purpose of the demonstration program was to investigate the use of bags for solid waste storage and collection. The objectives of the study consisted of the following: (1) evaluate the effects of disposable containers on collection efficiency; (2) compare paper and polyethylene bags with cans for use as solid waste containers; (3) determine householder preferences for disposable versus reusable conventional hard containers; (4) investigate health, safety, and environmental factors related to the use of disposable containers; (5) study alternative methods for distributing solid waste bag systems; (6) suggest incentive programs for using bag systems; and (7) investigate the feasibility of using polyethylene liners in large bin containers.

B. Demonstration Program Procedure

1. Study Approach. Three demonstration areas were chosen in the City of Inglewood; two were single-family residential areas, and one contained both single and multiple family dwellings. Each area was subdivided into two comparable routes, one of which was the test route to receive bags, and the other to serve as a control.

A four-week pre-demonstration study was undertaken prior to the distribution of bags to define basic field conditions in the demonstration areas. The objectives were to: establish crew performance; determine the number of cans collected per residential unit; measure the solid waste quantity per residential unit; and define operating parameters for collection crews and equipment. Statistical methods were used to establish the equivalence of the paired routes on the basis of number of containers, quantity of solid waste, and types of waste.

Additional samples of Inglewood solid waste were taken for all study areas during three different periods of the year to define seasonal variations in composition.

2. Distribution of Bags to Householders. Four basic household bag systems were evaluated during the demonstration: (1) the paper bag and holder; (2) the polyethylene bag and holder; (3) the polyethylene can liner; and (4) a free-standing paper bag. Specifications to supply bags and holders were offered to prospective bidders, and bids were received from six companies.

The number of bags and holders required for the test periods were estimated for both single family residences and for apartment buildings, from the pre-demonstration field studies. Bags were distributed by City collection personnel who explained the purpose of the study to the participating householders. Each residence received three separate distributions of bags at three-month intervals in order to allow sufficient time to establish performance. Comparisons were made between different container systems (cans, bags, and liners) and between different bag systems. A fourth distribution was made to an apartment condominium to evaluate a new liner holder, and to investigate bag collection utilizing holders on the residence property. Four questionnaires were distributed: one at the end of the two test periods, one at the condominium, and one to the three test areas to evaluate the householders' overall response to the bag systems.

3. Field Data Collection. Field data were gathered on collection time, the average quantity of waste per stop, the average number of containers of a given type per stop, and the size of containers in use. Additional field work consisted of counting the number of bags with punctures, tears, and those failing. Field monitoring was continued after the 3-month bag distribution and use periods to count the number of residences voluntarily using bags. Special field time studies and personal interviews with bin liner users and landfill personnel were completed.

C. Results of Field Studies

1. Collection System. Time and motion studies were conducted on the six test routes, and collection time and associated container size and weight data were recorded. Analysis of the data indicated that on routes using bags, average collection times per stop ranged from 17 to 25 percent lower than on routes using conventional containers.

During the field time studies, the project engineers observed that it was easier to handle polyethylene bags than paper bags due to the method of closure. Collection time comparisons made between two routes using only paper and polyethylene bags, respectively, indicated that collection time averaged about 0.02 minutes more per bag for paper than for polyethylene bags. This difference may have resulted from the greater quantities of waste contained in paper bags. It was not, however, statistically significant.

Statistical comparisons of the average number of items per collection stop in paired bag and control routes showed that there was a significantly greater number of items per household for bag routes than for can routes in two study areas (B and C), and no significant difference in one area (A). Although the estimated solid waste capacity of the bags was within 5 percent of the cans, the actual capacity utilized in the bags was about 20 percent less than in the cans. Only large can liners were found to contain as much solid waste as the cans. This was due to: loss of bag capacity as a result of rolling the edge over to close the bag; and the improved compaction of solid waste in hard containers which support the bottom and sides of the bag.

2. Public Health and Environmental Considerations

a. Noise. Measurements were made of the reduction in collection noise resulting from replacing conventional metal containers with disposable bags. The "noise rating number" is a measure of noise level related to probable hearing annoyance; when it is greater than 85, hearing may be affected detrimentally. The noise rating number of 86, measured when metal containers were struck against the side of the collection truck hopper, posed a potential hazard to the hearing ability of the collector. Use of disposable bags would eliminate this potential noise hazard. In addition, a reduction in vehicular noise from the packer and motor mechanisms would be desirable to reduce the noise level below 85. Noise rating numbers taken during dragging and dropping of cans and bags were 37 percent lower for bags than for cans.

b. Insects. A study of fly generation in household waste bags at the City of Inglewood was conducted in cooperation with the Department of Public Health of the State of California. Green blow files have a life cycle which is well-suited to breeding once-a-week between collections, and consequently are often produced in excessive numbers in solid waste containers. Data collected on the total number of green fly larvae migrating from conventional solid waste containers with and without polyethylene liners showed that the amount of fly production would not be sufficiently reduced by polyethylene liner use to warrant its recommendation for fly prevention. The old cans, although cleaned prior to the fly study, may have acted as a fly source even with the liners due to subsequent deposition of waste. Fly control might be improved by using containers with open bottoms to hold the liners, as is done in Manchester, England.

c. Litter. A measure of littering, labeled the "litter index", was developed to compare littering in different areas before and after collection. Litter classified by maximum dimension and surface area showed that most litter items had surface areas in the range of 2 to 3 sq. in. and 10 to 20 sq in., and a maximum dimension in the range of 1 to 5 in.

A mean litter index was measured immediately prior to collection. The mean litter index for can routes, 71.6, was almost double that for bag routes, 40.3. An average of 6.1 and 4.1 items were found on the can and bag routes, respectively. No litter was observed on the bag routes after collection, but litter was observed in two areas on the can routes. Counts of spills indicated occurrences of 1.2 percent for the 919 bags and 0.9 percent for the 5,427 cans observed.

d. Accidents and injuries. More than half the lost-time injuries occurring in waste collection during the six-month period studied in 1967 resulted from handling metal or other hard cans. The main injuries were strains, sprains, and dislocations resulting from lifting or carrying heavy, unwieldy cans or tripping over obstacles in walkways. During the conduct of the two-year demonstration in Inglewood, no injuries to collection crews were reported as a result of bag handling, but two injuries occurred on the can routes. The reduction in work hazards for the collector loading bags was due to: the limited weight load capacity; elimination of the extra weight of the can; elimination of jagged edges on cans; reduction in dust particles and pathogenic organisms in the air; and reduced noise. Some of the detrimental effects noted with bag use were their poor protection against sharp objects in the waste, and their tendency to burst during the vehicular compaction cycle and scatter dust particles.

e. Microbiological and dust tests. Bacteriological plates were exposed near containers as they were emptied into the truck hopper. It was assumed that the number of bacterial colonies which developed on the plates after incubation was proportional to the dust in the air. Comparison of the dust generated by use of bags and conventional cans was made.

Bacteria and fungi plate counts were made after 24 and 48 hour incubation times for two sets of samples, one for bags and one for cans. Analysis of the results showed dust generation decreased over 90 percent when using bags in place of cans.

A detailed analysis of the bacteria, fungi, and yeast varieties present in the dust samples was made to identify potential pathogens. Many pathogenic organisms were found in the samples taken during waste collection using conventional cans.

A controlled experiment investigated the extent of dust distribution when loading a collection vehicle with solid waste using can containers. The test results showed that during solid waste collection under windless conditions, cans may distribute solid waste dust as far as 14 feet from the point of dumping; thus dust is not confined to the collection vehicle. Also the greatest dust concentration may occur some distance from the loader in the direction the waste is dumped, and that dust may be inhaled by the collector if he is downwind of the field source.

3. Landfill and Transfer Operations. The disposal of polyethylene bags in landfills produced improvements in pushing and spreading operations, reductions in blowing of solid waste and dust, and reductions in odor. Some problems with polyethylene bags lodging between crawler tracks and dozer frames were encountered in maneuvering in wet weather; and fine grading of the compacted solid waste surface was more difficult with polyethylene bags. Calculations showed that polyethylene bags would increase the total wet weight of plastics in solid waste by about 50 percent. The limited biodegradability of polyethylene is not expected to cause significant problems in landfills. In addition, the combustion by-products of polyethylene are harmless. Paper bags treated with waterproof resins would similarly have little total environmental impact on landfill or incineration disposal.

Observations at a waste transfer station indicated that transfer station operations were generally improved by reductions in dust and blowing litter when solid waste in bags was handled.

4. Commercial Bin Liners. Polyethylene liners of 2 and 3 cu yd size for use in equivalent sized waste bins were distributed to a number of restaurants in the Inglewood area. The restaurants cited difficulties in handling and fitting, and improvements in sanitation, fly, and odor problems. Problems with the liners staying in bins during dumping were reported during collection. The overall popularity of the system was indicated by the unanimous approval of the responding users and their recommendation for continued usage. Time and motion studies during bin collection showed an average increase of 0.2 minutes per bin serviced. Economic analyses indicated a net increase in cost of about $117 per restaurant per year would occur as a result of increased collection time and liner costs.

5. Householders' Preferences. Five householder questionnaires were distributed to obtain the reactions of the residents of Inglewood to the demonstration bag systems.

Questionnaire 1 was a pre-test questionnaire to evaluate citizen interest in bags as solid waste containers. The overall response indicated the present collection service was viewed as very satisfactory, and that a change to bag systems would result in few apparent benefits. This response was prompted by the public being accustomed to a particular level of service and being unaware of possible improvements.

The goal of the four follow-on questionnaires was primarily to delineate the overall effects of using bags in place of metal or plastic cans, and secondly to compare the performance of the different types of demonstration bag systems and bag types based on the residents observations.

The responses to the questionnaires gave consistent reports on improvements and difficulties encountered with use of the bags. The majority of residents felt that the use of the bags resulted in marked improvements in all areas of solid waste management with particular improvements noted in ease of carrying filled bags, and neighborhood appearance, with less odor, fly, and spillage problems. Some difficulties with paper bags were reported in mounting, filling, and closure. The paper bags also required more storage space and were more susceptible to tearing when wet. Many of these problems were attributable to the novelty of the systems, and would be overcome with continued use and improved holders.

Polyethylene bags were waterproof and had a better method of closure which provided the collectors with a handle to grab. Polyethylene bags were punctured by brush or pointed objects more often than paper bags, although the paper ripped more easily after puncture. The collectors strongly favored the use of disposable bags and in particular the polyethylene bags which facilitated loading when tied closed. The overall response showed that the majority of the residents liked the bag systems and wished to continue them.

6. Voluntary Bag Use. A six-month follow-up survey to count residences voluntarily using bags showed that commercially available 1.5 mil polyethylene bags

were replacing the demonstration's specially purchased and more expensive 2.5 mil polyethylene bags; but, generally, usage of both paper and polyethylene bag systems decreased. All users apparently discriminated between bag systems largely on the basis of cost. A rise in use was noted in June 1970 when two local department stores began advertising promotions for 1.5 mil polyethylene bags.

7. National Survey on Usage of Disposable Bags in Solid Waste Collection Systems. A nationwide postal survey was made to define factors affecting the use of disposable bags for solid waste collection. A total of 205 cities representing a population of more than 36 million people responded.

Analysis of the responses showed that although many cities did not permit the use of bags, the majority had plans for allowing disposable bag usage in the future. Bags were already in use in approximately 12 percent of the households of the cities permitting their use, with 87 percent of the bags being used reported as polyethylene and the remainder as paper bags. In most instances, the bags were purchased privately by householders. The questionnaire responses indicated that the cities were generally satisfied with their performance. Polyethylene bags (1.5 mil thickness) cost less than paper bags when purchased in retail stores or at wholesale.

The cities reported that the main problems encountered in bag use were: the susceptibility of polyethylene bags to tearing, and of all bags to attack by animals; and the possibility of nonbiodegradability of polyethylene bags in landfill operations. Generally, however, these problems were not considered critical. Approximately 73 percent of the cities responded favorably to polyethylene bags as liners as opposed to bags on holders. Only 14 percent of the cities had conducted economic studies on possible savings resulting from the use of disposable bags.

D. Bag and Liner Materials Testing

Laboratory tests were performed on bag and liner materials to define physical properties that directly affect their economic value and field serviceability. The tests also helped to develop material specifications for the demonstration bag purchases.

Tensile tests were performed to obtain stress-strain relationships for the demonstration bag materials and to find the tensile failure levels for a number of other bag specimens. Supplementary tensile tests were performed under a variety of simulated field conditions to determine the effects of moisture content and absorption, evaporation, puncture, and creep.

Tensile tests illustrated the anisotropic, non-ductile nature of the two-ply paper specimens and the elasto-plastic nature of the polyethylene specimens. Soaking in a variety of common household waste substances such as water, cottonseed oil, and butter, and exposure to normal ranges of climatic temperatures did not significantly affect the tensile strength of the polyethylene materials; the strength of wet paper specimens was, however, 50 percent lower on the average when soaked in these waste substances than in the dry state. Other tensile tests showed that when polythylene bag material was punctured or perforated the decrease in failure load with an increase in the size of the puncture or perforation was less than the decrease for paper. Tests showed creep to be insignificant under normal residential solid waste bag loads.

Results from the laboratory tests were used to develop purchase specifications and to investigate correlations between laboratory test results and field performance. The ultimate strength and the strain energy of the polyethylene and paper specimens were found to be significant performance indicators correlating with field failures resulting from punctures and tears during actual use.

E. Formulation of Bag Evaluation Criteria

Bag system evaluation criteria were developed to satisfy the following objectives: to establish minimum standards for proposed bag material specifications; to provide a rationale for comparing bag system performance; and to formulate bag system selection criteria. Two approaches were developed for evaluating bag systems; the first related the properties of the bag materials to the bag failure rates in the field, while the second was derived from consumers' preferences and field performance.

Properties of the demonstration bag materials were derived from the laboratory tests, and a theory was developed which indicated that the energy absorption potential of the material (the product of the strain energy and the thickness of the material) was a measure of the field performance failure rate. This hypothesis was supported by a variety of field and experimental data.

Since the responses to the demonstration questionnaires indicated that the rate of failure of the demonstration bags was satisfactory to both householder and collector, minimum values of energy absorption potential and also of ultimate tensile stress of the demonstration bags were taken as specifications for the initial selection. Two selection criteria, one for paper, and one for polyethylene bags, were developed as minimum acceptable specifications in selecting bags on the basis of cost per unit volume of the individual bags. Paper and polyethylene were treated separately due to the different nature of their materials properties. An optimal bag material composition was not deemed a feasible parameter for bag selection; the strength and failure criteria are more applicable because they may be used to evaluate all bag materials. Polyethylene bags would be preferrable to paper in wet, damp climates and for the solid wastes of high moisture content. Bag volumes in the 32 to 36 gallon range and 55 inch circumference are satisfactory for household waste disposal. Larger bags of about 40 to 45 gallons with 70 inch circumferences are required for disposal of yard trimmings because of the larger opening and capacity to hold bulky brush.

An additional study approach was an algorithm formulation for total evaluation of bag suitability. This approach accounted for factors which affected bag performance other than failure rate and cost; for example, ease of bag closure, odor control, etc. The questionnaire data indicating the importance householders attached to each individual factor was incorporated with the field preference ratings of the demonstration bags to give a total rating for demonstration bags, which enabled a direct comparison to be made between each of the bag systems. Based on the algorithm analysis, the polyethylene bags and the polyethylene liners rated higher than the paper bags. The effect of poor bag holder performance on bag ratings was illustrated when a revised Mobil* holder was substituted for an old model. The algorithm reflected the holder substitution in a rating change for Mobil bags. The consistency and sensitivity of the algorithm ratings indicated that the format for total bag evaluation provided a workable rationale for comparing the overall suitability of bag systems for field use.

F. System Simulations for Cost Analysis

The impact of disposable waste bags on collection efficiency was investigated using a mathematical model developed by the project engineers. The model defined the time required for waste collection, and by using actual cost data for labor and equipment, collection costs were estimated for a particular service. Variations in field conditions were included in the model to determine their effect on waste collection efficiency. An IBM 360 computer was used to analyze alternative simulated collection operations.

Model simulations indicated reductions for bags over cans, using one-man crews, as follows: collection time, 21.7 percent; man-hours per ton, 15.4 percent, on the average, for 25 to 35 cu yd trucks; average cost per service, 6 cents (Inglewood costs); and the number of services a collection crew completed in a normal working day increased by 27.8 percent. Calculations comparing crew sizes of one, two, and three men showed the one-man crew to be the most economical for curb pickup.

G. Collection System Management Cost Analysis

Cost comparisons were completed for seven container configurations: (1) metal cans; (2) light duty plastic cans; (3) heavy duty plastic cans; (4) 1.5 mil thick polyethylene liners in metal cans; (5) 1.5 mil thick polyethylene liners on holders; (6) paper bags on holders; and (7) 2.5 mil thick polyethylene bags on holders. Costs were compared for City distribution and wholesale purchase of bags, and for resident retail purchase of bags. The present conventional can system, at retail, costs $1.05 per household per year less than the liner-in-can system, which was the least expensive of the four alternative bag/liner systems.

If the cost to the City for distributing liners could be constrained to be less than $2.44 per household per year, the liner-in-can system would become economically feasible.

Estimated benefits accruable to householders in the amount of $6.76 per household per year resulting from savings in can cleaning time and materials, provide an additional incentive for bag use.

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*Mention of commercial products does not imply endorsement by the United States Government.

H. Implementation of a Bag System for Waste Collection

Implementation of a bag system for waste collection should start with a comprehensive systems analysis of the collection operations. The collection time and cost savings presented in this report apply only to curb collection where residents carry the waste to the curb. Other collection systems such as back yard pick-up or container placement at the curb by collection personnel, would require complete time and motion studies to determine the potential savings attributable to using bags.

The following steps would be a necessary part of a complete systems analysis prior to implementing a bag collection system:

1. Complete extensive time and motion studies of the existing collection operation.
2. Determine the number of containers, container sizes, and the average quantity of waste collected per residence.
3. Estimate the collection time for bags by one of the following:
    a. Use Method-Time-Measurement (MTM) techniques applied to step 2, (see Appendix 1 and reference report 2).
    b. Conduct a small-scale bag use study and measure collection times on representative routes.
4. Determine the potential savings in collection time for bags versus cans from steps 1 and 3.
5. Select a bag or liner system using the bag evaluation criteria and algorithm for bag suitability presented in this report. A cold or wet climate may introduce additional factors into the selection process.
6. Estimate the collection system operating costs based on equipment, labor, and bag costs for alternative bag purchase and distribution methods.
7. Determine the economic feasibility of a bag system. If feasible:
    a. Establish an incentive program for bag system implementation based on the applicable cost, environmental and public health considerations.
    b. Develop an educational action program to introduce a bag collection system.

CONCLUSIONS

1. Polyethylene and paper bags are satisfactory solid waste container replacements for cans. Results of a Nationwide survey conducted by the project engineer indicated that bags performed satisfactorily in all climates; and that both public and private bag distribution methods were practiced.

2. The most frequently cited reasons for the slow rate of bag-system acceptance were management difficulties in achieving economical bag distribution and storage methods.

3. Prior to using bags, householders in the Inglewood demonstration areas were not concerned with further improvements in their collection system due to three factors: 1) the implied change in daily routine; 2) anticipated increase in cost; and 3) satisfaction with the existing system. After using the bags, however, the Inglewood householder participants indicated positive acceptance of the demonstration bags and can liners.

4. Reduction of litter and the absence of empty cans at curbside after collection improved the neighborhood appearance. The bags were directly responsible for reducing collection noise, dust generation during truck loading, and accidents and injuries associated with overloaded and/or sharp-edged cans. There was also a minor reduction in blowfly larvae counts with bag use.

5. Although the thin 1.5-mil, 32-gal polyethylene bag materials and construction commonly available as of 1970 were satisfactory, bags of 2.5 mil or thicker were torn or punctured less frequently.

6. The polyethylene bags and liners were waterproof, odor proof, required less storage space than paper bags, and closed easily. The paper bags lost 80 percent of their strength when wet, did not constrain odors, required 18 times the storage space of polyethylene bags, and were difficult to close when filled with waste.

7. At the break point, the dry tensile strength of the paper bag material was five times greater than that of the polyethylene material. The failure load of polyethylene bags decreased less than that of paper bags with increasing perforation hole size.

8. A properly designed holder is a desirable part of a bag system. Demonstration holders with malfunctioning lids prompted many negative comments, and influenced the householder against the bag type being used. An improved holder resulted in greater bag-system use satisfaction.

9. A lack of uniformity in the bag and holder sizes of competitive manufacturers sometimes precluded the use of one manufacturer's bag product on the holder of another manufacturer.

10. Simple bag closure ties were not available for paper bags, but were readily available for plastic bags.

11. The solid waste collectors indicated they favored the bags and liners over cans. They were saved the work of lifting and replacing cans and their covers after emptying. The polyethylene bag ties provided the collector with a convenient hand grasp which facilitated bag pick-up; the handgrasps contributed to a statistically insignificant 0.02 minutes less collection time per bag for polythylene bags over paper.

12. The full load capacity and number of units collected to fill the refuse collection vehicle were not significantly affected by bags when compared to conventional containers.

13. Polyethylene and paper bags reduced dust and litter in transfer station operations. Polyethylene and paper bags were observed to reduce litter and dust, and improve landfill spreading. Polyethylene bags increased by about 50 percent by wet weight the amount of non-biodegradable plastic material in the municipal landfill solid wastes. Polyethylene bag incineration would produce carbon dioxide and water vapor.

14. On the basis of utilized container capacity in volume and filled weight, about five 32-gal bags were required to replace four conventional 32-gal cans; analysis of field data indicated significant increases in the total number of items placed for collection from residences using bags over those using conventional containers. Paper bags were generally filled to a greater percent of their ultimate capacity than polyethylene bags, but to a lesser percent than cans.

15. Based on model simulation studies using field data and assumptions derived therefrom, paper and polyethylene bags reduced the average net solid waste curb collection time and related costs below that for cans. The use of bags instead of cans reduced maximum net solid-waste curb collection time as follows (including travel time between stops and to landfill, using a 25-cu yd truck): one-man crew, from 53 to 41 man-minutes/ton (23 percent); two-man crew, from 98 to 76 man-minutes/ton (23 percent); and three-man crew, from 123 to 99 man-minutes/ton (20 percent). Corresponding reductions in collection-system cost per service were about 24, 24.3, and and 17.5 percent for one-, two-, and three-man crews, respectively. The one-man crew is the most economical crew size. These cost reductions do not include the cost of bags, holders, and their distribution.

16. The use of bags increased collection-system productivity in the demonstration area by an estimated 27.8 percent in the number of stops serviced in an 8-hour day by a one-man crew and 35-cu yd truck, compared with that achieved with the use of cans.

17. Polyethylene 1.5 mil bag liners using cans as holders were calculated to be an economically feasible solid-waste container system for curb collection in Inglewood under the following conditions: wholesale purchase of the liners by the City; liner distribution costs of \$0.75 or less per residence per year; and the use of existing cans as liner holders.

18. Criteria for bag system selection were defined separately for polythylene and paper; the optimal bag provides the greatest strength at minimum cost within the following constraints:

Polyethylene: minimum cost per unit volume

subject to: strain energy $\geq$ 10.0 in-lb/in^2
ultimate strength (stress) $\geq$ 2000 psi

Paper: minimum cost per unit volume

subject to: strain energy (dry) $\geq$ 2.0 in-lb/in^2
strain energy (wet) $\geq$ 0.5 strain energy (dry)

The selection of polyethylene over paper may be required in wet climates and for disposing of solid wastes high in moisture content. An optimal bag composition and volume are not in themselves adequate criteria for selecting bag systems.

19. An algorithm for evaluating bag/liner system suitability was developed. It may be used to compare the relative merits of alternative bag systems, to locate defects in either the bags or holders, and is capable of being expanded to include new rating elements as they are defined. The algorithm data reflected the effect of a malfunctioning holder lid on the total bag-system rating.

20. The large (2 and 3 cu yd) demonstration bin liners improved sanitation and were well received by the restaurant users. The liners were, however, relatively costly and required more installation and collection time than unlined conventional metal bins.

RECOMMENDATIONS

Further studies are recommended in the following areas:

1. A follow-up program to formulate an optimal route collection system for the entire City of Inglewood using bags.

2. A study to determine optimum bag dimensions to set improved uniform standards for capacity, circumference, area of bag opening, and wall thickness, and to develop improved bag holders. Standardized, optimal bag dimensions could improve the working (used) capacity of the bags by reducing bag-filling problems cited in the present study; and standards for a universal bag-holder mounting and protection system, including a quick disconnect device for installing and removing both polyethylene and paper bags, would increase the efficiency and flexibility of the bag collection system.

3. Further back yard pick-up and other specialized solid waste collection system studies to evaluate the cost-benefits of using bags.

I. INTRODUCTION

A. General

Until recently, bags for solid waste have not received the widespread use in the United States as in some of the northern West European countries. Primary reasons for this slow acceptance may have been due to: the gradual evolution of collection methodologies in the United States, uncertainties of the potential benefits, the costs for the bag systems, the need to develop satisfactory methods for distributing bags, and the lack of extensive promotional activities by bag distributers.

The National Refuse Sack Council[1] reported in 1968 that 37 small American communities were using paper bags. They indicated that all of these communities, after once experimenting with the use of bags in a significant number of residences, decided to continue their use even though it appeared that additional costs were involved.

A variety of bag systems are currently being used. In some instances, the municipalities provide paper or plastic bags either free of charge or at cost. When bags are provided they are distributed by the collection workers or are made available to residents at convenient locations in the community. When the municipality does not provide bags, the individual householder must purchase them commercially. In addition, many types of enclosed and open bag holders are available for use with either paper or plastic bags.

The City of Inglewood solid waste collection system has been employing one-man crews for municipal collection service since 1960. The high level of service and economic success of this system has received attention since its inception. The City participated in a USPHS-contract study of one-man and multi-man crew size collection systems in 1967-68 to define the nature of the savings that could be achieved using a one-man crew. The results of this study were presented in a final report[2] published in mid-1969. The report and much of the detailed field work conducted during the one-year study period provided valuable basic information which was directly applicable to the bag demonstration program.

B. Objectives

The objectives of the demonstration program were to: (1) evaluate the effects of disposable containers on collection efficiency, (2) compare the use of polyethylene and paper bags as solid waste containers, (3) determine public preferences for the use of either disposable bags or conventional hard containers, (4) develop incentives for the use of improved containers, (5) investigate environmental health and safety factors related to the use of containers, (6) study alternative procedures for distributing bags and holders, and (7) investigate the use of polyethylene liners in large bins.

II. BACKGROUND ON BAG USE

A. Paper Bags

The practice of placing solid waste in a paper bag until the bag and contents can be discarded is common practice. What seems more natural in a kitchen, for example, than to place garbage and other solid waste into a small bag for subsequent disposal? However, providing the public with specially fabricated large bags and holders to replace traditional galvanized metal or semi-rigid plastic cans is innovative.

Experimentation with paper bags for use as can liners began as early as 1938 in the Borough of Croydon in London. The impetus for the British paper bag solid waste storage system was primarily the result of the World War II shortage of metal; this was also true in both Sweden and Germany. However, other special virtues of the system were realized when in 1954 bags were adopted for the hygienic disposal of soiled hospital dressings, infected linens, and other medical solid waste.

The introduction of a specially designed bag holder provided a means for supporting the bag in a semi-rigid receptacle and led to the further development of the paper bag system. Holders were first used in Scandinavia, and the first notable installation was probably in the town of Sandviken, Sweden, north of Stockholm. Since that time, Sweden and Denmark have led the way in technological improvements of paper bag systems.

In the Scandinavian countries, nearly all large disposable bags are made of wet strength paper. A major reason for this is that the plastic companies are owned by the well established paper industry. Thus the polyethylene bags have not competed with paper bags. In 1970 at Copenhagen, Denmark, paper bags and holders were distributed and maintained by the City free of charge to the householders. Ownership of the holders, however, remains with the City. Replacement bags are distributed to the householder by the municipal collector during back yard pickup of solid waste.

The United Kingdom is believed to have the greatest number of homes served by bag systems, which include those in such large cities as Manchester and parts of London. It is estimated that about 10 percent of the municipalities have switched entirely to the use of disposable bags since the initial development of systems began in 1958.[3] In 1960, following six months' experimental use of the paper bags in 250 homes, the rural Swale Borough District Council decided to adopt the system in a district containing 7000 homes. The United Kingdom also achieved success with the adoption of the paper bag system in the first new hospital to be built in the United Kingdom after World War II. The Ministry of Housing and Local Government, following a four-year investigation of solid waste storage and collection, endorsed the bag system in 1967. During the four-year study, three systems--ordinary metal cans, dustless bins, and bags--were evaluated. Recently, the usage of polyethylene bags has become increasingly popular because polyethylene bags are waterproof, less expensive, require less storage space and are easier to distribute. Estimates of the annual consumption of low density polyethylene for manufacture of bags in Britain have been increased from 1,000 tons in 1968 to 2,000 tons in 1970 and are expected to increase another five-fold by 1980.[4] Many municipalities were using polyethylene bags in 1970 on a test basis. It was common for polyethylene bags to be used on paper bag holders. In the City of Manchester, novel containers were developed for polyethylene bag liners; the containers have no bottom and are in the shape of an inverted truncated cone. The collector lifts the container and cover off the bag to allow its' removal to the collection vehicle and leaves a new liner on top of the container.

In 1970, it was determined by the project engineers that the local public authorities in the United Kingdom generally favored bag holders, and many authorities provided them at residences. However, the householders were somewhat reluctant to change, as they were reported to have favored the usage of bags as liners in metal cans. Many municipalities still use the old dustless system consisting of a metal or plastic container with special attached cover, and collected by a special vehicle provided by the municipality.

The use of bags for solid waste storage and collection in the remainder of Europe has been slow to develop in spite of intense promotion by paper bag companies. Only Germany showed some acceptance of the system. Eurosac, an association founded by paper bag manufacturers from 14 countries in Europe and Scandinavia, established a committee to facilitate the interchange of information and experience.

The pasted square-bottom paper bag has been used primarily in continental Europe and Scandinavia, while the United Kingdom has used the sewn bottom bag. In the United Kingdom it was less costly to manufacture the sewn bottom bag due to the availability of applicable types of manufacturing equipment, but the reverse was true in continental Europe and Scandinavia. Resins compounds and asphalt have been used as a means of bag waterproofing. The annual bag usage in Europe grew from 110 million in 1965 to 166 million bags in 1966, an increase of 51 percent.

Paper companies in the United States began promotion of the paper solid waste bag system in 1962. In 1967, the estimated total annual sales of paper solid waste bags in the United States had grown to about 20 million, and ten communities, with individual populations of 25,000 or less, required the use of paper bags by ordinance. There were, in addition, some 15 other communities that supported an optional system wherein local government supplied bags to the public at cost. In the United States, two-ply paper bags, impregnated with resin as a means of waterproofing, are commonly used.

The United States government has supported some research in the United States on the use of bags for residential solid waste. The 1965 Solid Waste Disposal Act provided grants to study solid waste problems. In 1966, a three-year grant was made to Barrington, Rhode Island, to demonstrate the paper bag system. Also, in 1962, the American Public Works Association, in conjunction with the Kraft Paper Association, examined the paper bag system under widely varying climatic conditions in four representative cities.[5]

In September 1968, the National Refuse Sack Council reported that 19 small cities required use of the paper bag system. Eighteen other cities were reportedly using the system on an optional basis, with the householder given the option of using the system if desired. The Council reported that a total of 90 towns in 1968 were involved in testing or special evaluation programs of the paper bag system. Many industrial, institutional, and commercial organizations were also users.

B. Polyethylene Bags

In contrast to the National Refuse Sack Council's concerted community promotional program, the polyethylene bag manufacturers, up until 1969, concentrated on the individual consumer as a market for their solid waste bag products. The gathering of information on polyethylene bag usage for solid waste containers in the United States has been difficult since there is no available industry-wide data. Individual companies have provided information regarding their own activities; however, they have been reluctant to divulge statistical data that might benefit their competitors. In 1969, the National Sanitation Foundation formulated proposed minimum criteria for polyethylene bags.

Manufacturers of plastic bags have conducted marketing tests for their products in selected communities located in various areas of the United States. For example, the Union Carbide Corporation tested plastic bags in about 850 households in Brockton and Malden, Massachusetts, from July to August, 1968. The positive response led Union Carbide to initiate national marketing and advertising of their waste bags in supermarkets and hardware stores. Perhaps the earliest tests of polyethylene bags in the North American continent were those conducted during 1965 at Toronto, Canada. Toronto authorities[6] reported that 140,000 solid waste bags were distributed to some 10,000 locations in the City. Other metropolitan Toronto communities have tested polyethylene solid waste bags and encouraged their use.[6] Montreal[7] has considered large scale use of polyethylene solid waste bags following a test period during Expo '67.

In 1965, tests of disposable polyethylene liners were conducted in the neighboring Cities of Lebanon and Monroe, Ohio.[8] A four-week test was conducted using polyethylene bags. In March 1968, 40 to 50 percent of the residents in the two latter Cities were using bags. Other cities in Ohio, Michigan, Maine, and Texas were also utilizing plastic liner bags.[8] Phillips Films Company, Inc., a subsidiary of Phillips Petroleum, following their marketing studies predicted that a 30 million dollar minimum annual market in municipal polyethylene liner bags would develop by 1973.[8] Based on a cost of 5¢ per bag, this 30 million dollar annual volume represents about 600 million plastic bags per year.

Important polyethylene disposable bag waste studies were completed in New York City in 1969 over an eight-week period. During the test some 17,000 households in various locations in New York City utilized the bags. Nine member companies of the Society of the Plastics Industry, Inc.: The American Can Company, Ethyl Corporation, Extrudo Film Corporation, Gulf Plastic Products Company, Mobil Chemical Company, Phillips Films Company, Sinclair-Koppers Company, Union Carbide Corporation, and USI Film Products, a Division of U. S. Industrial Chemical Company, in conjunction with the Society, contributed approximately 400,000 polyethylene solid waste bags for the test. The results of the test were favorable and led to the decision by authorities in the City of New York to modify their Health Code to permit, but not require, the use of plastic or paper bags for solid waste.

Other major cities in the United States experimenting with or permitting the use of plastic solid waste bags in 1970 included: Kansas City, Missouri; Flint, Michigan; Warren, Michigan; Kenosha, Wisconsin; and Alexandria, Virginia. The project engineers conducted a National survey of solid waste bag usage which revealed that a large number of cities throughout the Country are now permitting the use of disposable solid waste bags. A few cities are participating directly in the purchase and distribution of these bags to residents.

An indication of the potential size of the United States' market for disposable waste bags can be derived from the approximately 55 million households in the United States. Assuming an average bag usage of three per week at an average cost of $0.05 per bag, there would be a potential 400-million dollar annual market.

An impetus to the use of polyethylene bags has been the threat of strikes by the local collection workers. This threat has caused many local authorities to stockpile polyethylene bags. During strikes, the bags are distributed to householders by the authorities. Strikes have proven to be a major method for the introduction of polyethylene bag systems. To a lesser degree, paper bags have also been used during collection system strikes in 1969-1970.

C. National Survey on Usage of Disposable Bags in Solid Waste Collection Systems

A total of 205 cities in 43 states and the Virgin Islands, representing a total population of 36,448,000, responded to a nationwide mailed questionnaire survey on the use of disposable bags for solid waste collection. The survey questionnaire is presented as Appendix E. Of the 188 cities which responded to the question concerning city regulations, 55.4 percent (104)[a] permitted the use of bags and 44.6 percent (84) did not. The responding cities who allowed use of bags estimated that 12.2 percent of their householders used disposable bags, of which 87 percent were polyethylene and 13 percent paper. Of the 158 cities which replied to the question concerning future usage, 75.3 percent (119) indicated they had plans for future disposable bag usage.

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[a] Numbers in parentheses denote the number of cities providing data.

Disposable bags were purchased by the householders in 86.0 percent (116) of the 135 responding cities. In 7.4 percent (10) of the cities, the city sold the bags. In 3.0 percent (4) of the cities, the city supplied the bags free of charge. The disposable bag sizes most often used were in the 20-30 gal range. Of the 78 cities which responded to the question on bag size, 82.0 percent (64) used bags in this size range. The cost of the bags ranged from 7 to 15 cents for paper bags, and from 4 to 12 cents for polyethylene bags. Distribution costs were incurred by 3.5 percent (5) of the 136 cities supplying information. The city authorities were asked to give their opinion of the householders' reaction to the disposable bags. A 1 to 10 rating scale was used, ranging from very unsatisfactory to very satisfactory, respectively. The overall rating response of 6.92 showed that the city authorities believed the householders were satisfied with the disposable bags.

Several problems were reported resulting from the use of disposable bags. Of the 120 responding cities, 24.2 percent (29) reported that the polyethylene bags tore easily because they were too thin or overloaded. In 17.5 percent (21) of the cities, it was reported that cats and dogs sometimes tore the bags open and scattered the waste; 6.7 percent (8) of the cities were concerned that polyethylene bags and their contents would not disintegrate when buried in a landfill; and 5.0 percent (6) of the cities noted that bags sometimes burst open during loading due to their being improperly tied. No problems were reported by 42.7 percent (61) of the responding cities.

The city authorities were asked if they favored polyethylene bags as liners or as disposable solid waste containers with holders. Of the 144 responses, 73.1 percent (98) favored polyethylene bags as liners, and 26.9 percent (36) favored polyethylene bag and holder systems. Of 140 responses concerning bag preference, 69.3 percent (97) indicated polyethylene bags as being superior to paper bags, and 30.7 percent (43) indicated paper bags as being superior to polyethylene bags. Only 14.2 percent (24) of 169 responding city authorities were aware of any private collector firms which supplied disposable bags to householders. The questionnaire asked whether the cities had conducted any studies to determine cost savings resulting from the use of disposable bags. Of the 177 responses, 14.1 percent (25) reported having conducted studies, and 85.9 percent (152) reported they had not conducted studies.

III. AREA DESCRIPTION

A. General

The City of Inglewood is located within Los Angeles County in Southern California, as illustrated in Figures 1 and 2. The County of Los Angeles had an estimated January 1, 1970 population of 7,154,845 persons, of which Inglewood accounted for less than 1.4 percent, or about 94,000 persons. The population of Inglewood has grown with that of the Los Angeles area; it increased from 63,390 in 1960 to an estimated 94,000 persons in July of 1968. This gain of 37 percent has been directly related to the demand for close-in housing created by the expansion and growth of the Los Angeles Metropolitan area. The City of Inglewood Planning Department has projected a 1980 population of 125,000. Residential zoning density in the City, based on 1960 census data, varied from a low of 6.0 persons per acre to a high of 21.1 persons per acre. In 1968, an estimated total of 36,000 dwelling units were available, indicating a minimum average occupancy of 2.6 persons per dwelling unit.

Selected climatological information for the Inglewood area during the study period is presented in Table 1.

B. Solid Waste Collection

The City of Inglewood in 1957 established a residential solid waste collection service utilizing municipal crews and equipment. Prior to 1957, combustible waste was disposed of by householders in their private back yard incinerators. Wet garbage was collected twice weekly by a private contractor for disposal to hog ranches. The City maintained once-a-month collection of brush and yard trimmings. After 1957, the City initiated once-a-week curbside collection of combined waste, less garbage, using two-man crews. Historically and currently (1970), the City encouraged unlimited solid waste quantities for collection provided the householder's waste materials conformed to the municipal ordinance. The City's 1970 ordinance requires a maximum container plus contents size and weight of 40 gal and 60 lb, respectively; brush has to be tied in bundles not exceeding 4 ft in length, 2 ft in diameter, and 60 lb in weight. During the 1968-70 demonstration test period, once-a-week collection of combined waste was provided.

In 1961, following the initiation of combined collection of all types of waste at the curb location, the City of Inglewood experimented with one-man collection crews. Combined waste collection was made possible by a change in the Los Angeles County solid waste ordinance to permit disposal of wrapped garbage in sanitary landfills.

The implementation of one-man collection operations by the City of Inglewood was prompted by the availability of large size collection equipment with each vehicle traveling the relatively long haul (30-mile round trip) distance to the Los Angeles County Sanitation Districts' Mission Canyon landfill disposal site, shown in Figure 1.

A transfer station was considered as an alternative procedure; however, its use was determined to be less economical than the aforementioned method. Historical information describing the collection system tonnage and man-hours is presented in Table 2. Performance rates were calculated based on paid direct collection labor hours including supervisory personnel and tonnage from scale receipts. Collectors were paid for a minimum of eight hours work each day. Average load sizes have increased partially as a result of converting the collection vehicle fleet from 20 cu yd trucks capacity common in the 1960-62 period to 25 and 35 cu yd capacity trucks in the 1964-70 period. In 1970, the City of Inglewood collection fleet consisted of eighteen 35 cu yd and three 25 cu yd collection trucks.

IV. AREA EVALUATION AND DEFINITION

A. Study Methodology

Control studies were undertaken prior to the distribution of candidate bags to define basic field conditions within the demonstration areas; to establish crew performance collecting conventional hard containers; to ascertain the comparability between the study areas; and to define operating relationships between collection crews and equipment. Other special field work completed prior to the distribution of the bags included a noise study and a survey of resident attitudes toward the waste collection system used prior to the demonstration.

Three test areas, designated A, B, and C, were chosen following field analysis and discussions with City of Inglewood authorities. Street maps of the three test areas and their location within the City of Inglewood are shown in Figures 3 to 6. Areas A and B are located in single-family residential areas, whereas Area C contains both single and multiple-family residential dwellings.

Each area was subdivided into two waste collection routes: one to receive bags during the study; the other to continue using conventional containers as a control for evaluation and comparison of differences resulting from the use of bags.

Each route size corresponded to the daily work assignment for one crew. The same truck and crew were to be employed on each route for the duration of the study.

The rate of collection as measured by man-hours per ton, is dependent upon the solid waste weight collected per stop; the number, type, and location of containers; the work rate of the collector; the travel time between collection stops; equipment characteristics; and the haul time between the route, landfill and garage. Daily and seasonal variations in solid waste quantity, weather, and human factors affect crew performance. Each collector used the same type of equipment and all collections were made from the curb or alley location to minimize the effect of these variables in the comparison study. Statistical analysis was used to establish the comparability of the paired routes in each of the three study areas.

B. Route Information

The preliminary field studies were conducted during the Fall of 1968 and consisted of determining the following data for each route:

1. Type and number of residences.
2. Type and number of waste containers at each collection stop and the associated collection times.
3. Average quantity of solid waste per collection stop in lbs.

4. Route mileage.
5. Lot widths in ft.
6. Incidences of container spills.
7. Travel time between collection stops in min.

Individual times for collection and travel were obtained with incremental time recording equipment, illustrated in Plate 1A. Times were recorded to the nearest hundredth of a minute. Video tape recordings were also made to evaluate motion-time-measurement (MTM) data.

Four weeks of preliminary field studies were conducted on each of the six routes. Statistical analyses were completed on selected data as tabulated in Tables 3 through 8.

Table 3 contains the number and type of residences and the length of each route. Lot widths in Areas A and B averaged 50 ft. Lot widths in Area C were greater and varied widely due to subdivision for apartment houses. Tables 4 and 5 show the mean and standard deviation of the number of containers located at each collection stop. Table 4 includes cans only, whereas Table 5 includes cans and all other items placed at the stop for collection. Single family homeowners typically used 32 gal capacity galvanized iron metal cans, while apartment houses typically used 40 gal galvanized iron metal cans. Collection stops were classified as either single or multiple family residences. The bottom row of numbers in each table indicates the total number of data points comprising the sample.

Tables 6 and 7 contain the mean and standard deviation of the collection time per stop and the travel time between stops, respectively. Data for three weeks of field study is reported in Table 6 because during one week the trucks on some routes were operated by different collectors.

C. Comparative Analysis

A test of significance[9] was conducted on the mean number of cans and other items (cardboard containers, etc.) per stop for paired routes. The comparisons between routes were made for each week of the four-week field study. Table 8 contains results of one series of calculations for paired routes A1 and A2, and is representative of similar calculations made for routes in Areas B and C.

Since the calculated values for the significance level (U) in Table 8 lie between +1.96, it was concluded with 95 percent confidence that the number of items placed for collection at each stop was similar in routes A1 and A2. Calculations similar to that of Table 8 revealed satisfactory comparability at the 5 percent level of significance between routes B3 and B4, and C5 and C6 for the number of cans and items per living unit.

Table 9 indicates the average quantity of solid waste collected per residential unit. The data was obtained by weighing the contents of each fully loaded truck and dividing by the actual number of residential units served by the truck.

The lower quantity per living unit in Area C is believed to reflect a lack of yard trimmings in the apartment house waste. Commercial gardeners normally removed yard trimmings from these latter apartment houses as part of their work activities.

The work performance level of collectors operating in the study areas was established as a base to identify and measure changes in collection efficiency resulting from the use of bag systems. Measurements were made over a four-week period to establish the time required for each crew to load cans, and combinations of cans and other items. Other items are defined as one-way containers, such as bags, boxes, and bundles of newspapers, and yard trimmings, etc. The average time to collect a stop composed of 1, 2, 3, ... 7 cans and a similar number of other items was plotted; stops having greater than seven items comprised less than 5 percent of all stops and therefore were not included in the figures. The performance of collectors on paired routes, as represented by a least squares line of collection times, calculated from data on all stops and items, is illustrated in Figures 7 through 12. Similar comparisons of collection time for bags were made following the demonstration tests.

Examination of the figures indicates that collectors operating on routes A1 and A2, and on B3 and B4, were similar in their rates of loading for cans and other items. Collectors working in Areas C5 and C6 were somewhat dissimilar when compared to those operating in Areas A and B. The differences were attributed to the larger capacity containers employed at the apartment houses in Area C since the same routes, collectors, and vehicular equipment were utilized when bags were distributed for field testing. The time to collect a given number of cans only was greater than the time to collect an equal number of items (including cans).

D. Composition of Inglewood Solid Waste

A sampling program was initiated in the Fall of 1968 to determine the composition of Inglewood residential waste. Samples were obtained from study Areas A, B, and C during three periods of the year to account for seasonal variations. There were a total of 1,522 collection stops in the three study areas. The number of stops sampled in the study areas was selected to give a statistically reliable sample of the total population of stops in the three areas. The number of samples taken in each area was proportional to the total number of stops in the area and was based on the measured variations in the quantity of waste per stop shown in Table 9. The confidence level for the refuse sampling program was 60 percent. Locations for sampling within each area were chosen using a random number table. Samples were taken during one-week periods in November 1968, February 1969, and July 1969. At each stop, the weight of solid waste and the number, type, and weight of each container were recorded.

The solid waste materials were subsequently hand segregated into five categories. Typical waste materials grouped into each category on the basis of material composition were as follows:

Class 1 (Low Moisture Fibers)

- Paper
- Cardboard
- Lumber
- Cloth
- Leather

Class 2 (High Moisture Fibers)

- Grass
- Leaves
- Hedge Trimmings
- Branches
- Green Wood

Class 3 (Metals)

- Ferrous
- Non-Ferrous

Class 4 (Inert Materials)

- Plastics
- Rubber
- Glass
- Ceramics
- Concrete
- Dirt

Class 5 (Putrescibles)

- Food Scraps

Laboratory samples were taken for organic and moisture content analysis. Table 10 indicates the results. The Class 2 materials have the highest average moisture content; these materials, however, absorb very little moisture but may hold some on their surface. The Class 1 materials, while low in moisture content, are high in moisture absorption capabilities. Class 5 materials varied the greatest in moisture content (558.9 to 20.8 percent, dry weight). Class 1 materials are of major concern since they absorb large amounts of water during rainfalls; the waste samples collected in area B during February 1969 (Table 10) experienced a heavy rainfall prior to and during sampling, which was reflected in the exceptionally high moisture content of the Class 1 materials.

V. DISTRIBUTION OF BAGS TO HOUSEHOLDERS

A. Specifications For Bag Purchases

Specifications prepared for the purchase of bags and holders for use during the demonstration were based upon suggested National Refuse Sack Council specifications modified by results of the laboratory studies. Separate specifications prepared for the purchase of polyethylene and paper bags with suitable holders are included as Appendix C.

The preparation of specifications was complicated by the wide diversity in commercially available bag sizes and holders. Although it was desired to permit all potential bag or holder manufacturers to submit a bid, it was necessary to limit the alternatives so that meaningful field studies could be made. The specifications provided options for two sizes of paper and two sizes of polyethylene bags. Only the polyethylene bag manufacturers were able to manufacture specific bag sizes different from their normal product line and in the quantities desired for the field studies. Polyethylene bags of 1.5 mil thickness initially were not considered strong enough, but since they are sold commercially and used in many communities, a 1.5 mil liner was subsequently purchased for the demonstration.

Closures for the paper system were not available when the specifications were formulated; however, a closure on the filled bag was desired. A wire tie closure was common for the plastic bag system. Specifications requested paper bag manufacturers to indicate their company's closure system. No response was received from any paper company on this item of the specification.

The use of the bags in apartment units led to the specification of a larger than normal size can liner fabricated from polyethylene material for use in 40 gallon containers. A proportionally heavier thickness was specified to handle the additional weight of refuse expected in these larger containers.

B. Bid Analysis

Specifications to supply solid waste bags and holders for the demonstration studies were offered to prospective bidders in February 1969. A list of companies who indicated interest in supplying bags for the studies is included as Appendix D. The bidders list is not intended to be a complete tabulation of national bag manufacturers. Bids were received from six companies, two of which offered to supply both paper and polyethylene bags. The analysis of the bids received was based upon the following criteria: need for the purchase of discreet quantities of alternative bag and holder types in order to meet project objectives; compliance with specifications; and price.

Bags and holders purchased for field studies are summarized in Table 11.

Three basic bagging systems were evaluated during the conduct of the demonstration. These included: the paper bag and holder; the polyethylene bag and holder; and the polyethylene liner using conventional hard containers as holders. A small number of free-standing paper bags were also tested.

These systems are illustrated in Plates 1B, 1C, 1D, and 1E.

C. Bag Distribution Schedule

Three separate distributions of bags were made as follows: the first in each of the three study areas; the second in Areas B and C; and additional special distributions in Area A1 and the Briarwood condominium. The distributions, summarized in Figures 13 to 16, were designed to enable householders and apartment building managers to make comparisons between alternative bag systems.

Demonstration residential units in Areas B and C, and the Briarwood condominium were allocated three-month bag supplies for each candidate system tested, and units in Area A were given a 6-month supply. At the close of the initial three-month test period the cooperating householders were asked to complete a questionnaire (see Appendix E2, Questionnaire 2) and they were then supplied with a different bag system. At the end of the second three-month period, Questionnaire 3 (Appendix E3) was distributed to obtain comparative evaluations of the different bag systems used by each resident.

D. Allocation Criteria

The allocation program was designed to provide a specific bag system and initial bag supplies for testing in residential living units in the three study areas. Estimates of the rate of bag usage were used to project the number of holders required for each test apartment complex. Apartment managers handled the bags.

The initial assumptions used for the allocation of bags and holders to residences in each of the study routes for the first distribution were as follows:

Single family homes:

bag on holder - average usage of 3 bags per week
liners for container - average usage of 2 liners per week

Apartment buildings:

holders - one for every three apartment units
liners and bags - two per week per apartment unit

Estimates of the rate of bag usage for the second and third distributions were based on field counts of actual bags used by residents during the initial demonstration period, and the allocation program was modified to distribute bags on the basis of their use per household during the first three-month period.

E. Distribution Method

Regular City of Inglewood collection personnel distributed bags and holders to the participants in the study. Based on the allocation program, the designated number of bags for the duration of the study was estimated and pre-packaged for each residential and apartment unit. A master list for each route was prepared indicating the resident or apartment house manager's name, the number of bags by type, and the number and type of holders delivered.

Representatives from two bag manufacturing companies assisted in explaining the purposes of the study and the proper procedures for use of the particular bag system to the study participants. The residents were instructed on the significance of their participation in the study, and they were asked to use their bag system exclusively during the test period. In general, the residents were cooperative. Only two of the households, or 0.7 percent contacted, on route A1 refused to use bags on the first and second distributions, and one household, or 0.3 percent, refused on route B4 for the first two distributions.

VI. DEMONSTRATION FIELD STUDIES

A. Collection Operation Studies

1. Effect of Bags on Collection Time. Following the distribution of bag supplies and holders in the three demonstration areas, field studies were initiated to evaluate the effects of bags on the solid waste collection system. The two more comparable routes, A1 and A2, were chosen for gathering time and motion data. Route A1 was provided with bags and route A2 remained a can route to act as a control on changes in collection operations attributable to factors such as weather, seasons, or solid waste character and quantity. Time and motion data was obtained for each area prior to the use of bags on October 22, 1968.

Collection time per stop for all items was recorded to the nearest two-hundredths of a minute. The stop times from the route before and during bag use were separately summarized in ascending order of magnitude and grouped into appropriate time intervals. The average number of items per stop on Route A1 were 3.93 and 4.21 on 10/22/68 and 5/20/69, respectively, and on Route A2, 4.26 and 3.88 on 10/22/68 and 5/20/69, respectively. The percentage of stops in each time interval was cumulatively summed in ascending order of magnitude to derive cumulative distribution curves which are plotted in Figures 17 and 18. A comparison of the plotted results illustrates the collection time savings attributable to the bag system. The median stop time for collection with cans was 0.5 min, and with bags 0.3 min, a median savings of 0.2 min per stop with bags. No random variations in median collection time, as illustrated in Figure 18, were observed in the control route. Thus, the variation indicated in Figure 17 is attributed to the use of bags.

Additional time studies were completed over a four-week period. Container data and associated collection times were recorded. Following tabulation, the collection times for the various numbers of cans, bags, and other container items were calculated for collectors operating on the six test routes. The data is represented by least squares lines on Figures 19 through 24. The tests indicated that the collection times for stops on routes using bags were substantially less than on routes using conventional containers.

A significance test was performed on the average collection time per stop between the paired routes in each study area. The difference between the mean collection time per stop for all stops on each paired route as indicated in Table 12 was significant at the 5 percent level. The differences indicate conversion to bags in the three study areas resulted in average time savings per collection stop ranging from 17 to 25 percent as shown in Table 13.

2. Mean Number of Items and Amount of Solid Waste Per Stop. In February 1970, field studies were completed on routes A1 and A2, comprised of single family residences, to compare the number of polyethylene bags used with the number of cans used by the householder. Data was collected from 222 stops on route A2 and from 250 stops on route A1. At each stop the number and types of containers and the solid waste weights were recorded. The analysis for each route consisted of determining

the average quantity of waste per stop; the percentage of stops having containers of a given type; and the average number of containers per stop. A summary of the results is presented in Table 14 and in Figures 25 and 26. The average number of bags used on the sample day (2.36 per stop) was less than the number of bags distributed per household; this results from seasonal variations in refuse and the use of cans by some householders.

The average number of items per collection stop in the routes using bags was compared to the equivalent value for can routes. Tables 15 and 16 summarize the data. Bag/can relationships are listed in Table 14 and the container distribution study routes in each area were compared statistically to determine if a significant difference existed in the mean number of items per stop. Statistical comparisons made between routes A1 and A2, B3 and B4, and C5 and C6 are summarized in Tables 16, 17, 18, and 19. At the 5 percent level, a significant difference in the number of items per stop was found in areas B and C. When area C data was reduced to reflect items per residential unit the significant difference remained.

3. Capacity Utilized in Cans and Bags. Additional field studies were conducted in the study areas to determine the capacity utilized in cans and bags. Table 20 summarizes the results. Although the estimated solid waste capacity of the bags was found to be within 5 percent of the cans, the actual capacity utilized in the bags was about 20 percent less than in the cans. Only the large liner bags were found to contain as much solid waste as the cans in which they were used. Since the liners were larger than the cans, their utilized capacity was lower. The data indicated that if the bags were filled to capacity, however, they would hold nearly as much solid waste weight as the cans even though it is easier to compact solid waste in hard containers than in bags.

4. Collection Time Comparisons Between Polyethylene and Paper Bags. During the conduct of field time studies, the project engineers observed that it was easier to collect polyethylene bags than paper bags. The method of closing the polyethylene bags with a paper covered wire tie provided the collector with a convenient handle for grasping the bag. Plate 2A shows a collector loading a polyethylene bag using this handle. In contrast, the paper bags were found to be loosely closed and therefore they were more difficult to grasp and lift into the truck hopper. A properly closed paper bag would probably provide a satisfactory hand hold for the refuse collector.

In the single family residential areas, A1 and B4, field data was obtained on collection time for stops which contained either all polyethylene or all paper bags. The collection time for each of these stops was noted along with the number of bags collected at each stop. The average collection times for stops with polyethylene and paper bags only were calculated individually as a function of the number of items collected. In area A1 a total of 122 stops containing only polyethylene bags was compared with a total of 307 stops containing only paper bags. In area B4 a total of 179 stops containing only polyethylene bags was compared with a total of 216 stops containing only paper bags. Figures 27 and 28 present the mean collection times as functions of the number of bags. The time to collect 6 polyethylene bags was greater than the time to collect 6 paper bags on routes A1 and B4 whereas the time to collect 5 paper bags was greater than for 5 polythylene bags. This appears to result from the collectors method of picking up bags, although the precise cause is not known.

Least squares lines fitted to the paper and plastic bag data on each route indicate that the collection time averaged about .02 minutes more per bag for paper than for polyethylene bags. The difference in the collection time between the polyethylene and the paper bags, while not statistically significant at the 5 percent level, may be attributed to the greater quantities of waste contained in the paper bags. As indicated in Table 20, with the exception of the polyethylene drawstring bag, paper bags contained in excess of 10 percent more waste than polyethylene bags as a percent of utilized capacity.

5. Condominium Time and Motion Studies. Waste collection in the Briarwood condominium in the City of Inglewood was studied for over four months. On two days, April 29, 1970, and May 27, 1970, special time and motion studies were made. On April 29, 1970, the study covered 366 condominium units from which 739 container items were collected. Of these 366 units, the data from 241 units was sufficiently complete for time and motion studies. On May 27, 1970, the study covered 430 condominium units from which 764 container items were collected. Of the 739 items collected on April 29, 1970, 406, or 55 percent, were disposable bags. Of the 764 items collected on May 27, 1970, 466, or 61 percent, were disposable bags. The collection time on April 29, 1970, averaged 0.35 minutes per condominium unit. The collection time on May 27, 1970, averaged 0.37 minutes per condominium unit. The tabulation of the detailed data is presented in Table 21.

B. Environmental and Safety Studies

1. Noise Survey. An important element in the maintenance of an aesthetic environment is the control of noise. The emptying and replacement of metallic containers is normally a source of obnoxious noise. The noise occurs when the metallic containers are struck against the loading hopper of the collection vehicle to dislodge tightly-packed contents and when the cans and their covers are replaced on concrete, asphalt or other hard surfaces. Because collection is begun during the early morning hours, these noises are more noticeable and may result in complaints by residents.

The replacement of conventional metallic containers with disposable bags eliminates this source of noise. The use of disposable bags has no effect on the noise resulting from mechanical operation of the collection vehicle and its packing mechanism. Noise studies on the conventional hard container system were undertaken in December 1968. The instrument used for measuring sound levels in the field and laboratory was a B and K sound meter, Type 2203, illustrated in Plate 2C equipped with an octave band analyzer. Sound level readings were taken of the following sources: background environment, collection vehicle motor, packer mechanism, hard containers being struck against the loading edge of the truck hopper, can placement upon concrete or asphalt surfaces, and placing covers on cans. Noise readings were taken at four distances from the truck hopper source: 2, 10, 50, and 100 feet.

The effect of noise upon humans varies with the intensity and frequency of the noise produced. Instrument manufacturers have devised sound weighting networks which are incorporated into noise measuring devices to indicate the relative effect of different intensity levels upon the human ear. The noise intensity is described in terms of decibels (db) and frequency is measured in cycles per second. Three weighting networks termed A, B, and C are commonly used in noise measurement. The A network response, since it corresponds roughly to the human ear's response to noise, was used for the field demonstration. The results are tabulated in Table 22.

For many evaluations the precision sound level meter survey results would be sufficient, particularly if the end use required only weighted sound levels. However, if two noises give similar meter indications, but sound differently to the human ear, then an octave band analysis is required to compare these noises. Corrections for background noise are important and necessary when the sum measurement (source plus background) is less than 15 db above the background noise levels. All field data has been adjusted as required for background noise levels.

A second common measure of noise levels, termed the "noise rating number", was employed. This number is related to the probable hearing annoyance that would result if a person were exposed to the noise for a given period of time. The "noise rating number", N, is defined as

$$N = \frac{L - a}{b}$$

where L = octave band sound pressure level in db
and a and b = constants.

The noise rating number was determined by measuring noise levels from a source in each of three octave bands with center frequencies of 500, 1000, and 2000 cycles per second which are known to affect the human ear most. The noise rating number formula was used to calculate the end value for each frequency and the number assigned to the source was then the highest of the three. A noise rating number equal to 85 has been used as a safe limit for conservation of hearing, because habitual exposure to such a noise level for 10 years may be expected to result in a negligible loss in hearing for an average individual. Values of a and b used in the formula to determine the noise rating number for the three octave band levels are presented in Table 23.

Noise rating numbers for the measurements made in the field over distances from the origin source of 2 ft, 10 ft, and 50 ft are tabulated in Table 24.

In general, the noise produced when containers were struck against the edge of the truck hopper resulted in the highest noise levels of the sources measured. At the 2-ft distance from the source (representing the approximate position of the collector) the noise rating numbers were below levels hazardous to the hearing of the waste collector. The noise associated with the banging of the waste container would be eliminated if disposable bags were used. For the Inglewood collection equipment, some reduction in vehicular noise from the packer and motor mechanisms should also be accomplished in order to reduce the noise rating number from 88 to below 85.

A second series of noise measurements was conducted to determine noise levels associated with dragging and dropping of metal containers and disposable bags on concrete, asphalt, and grass. Noise measurements were made at a distance of 35 ft from the source. The containers studied were loaded with 20 lb of paper waste and dropped from heights of 2 ft and 3 ft. Sound intensity measurements were made at frequencies of 500, 1000, and 2000 cycles per second. The respective numbers for asphalt, listed in Table 25, did not exceed 85. Only asphalt data are presented for comparative purposes because they produced the highest noise levels although they were below the safe limit.

The noise levels produced when plastic bags and paper bags were dropped on the three surfaces were about equivalent. However, only the noise levels recorded at the frequencies of 1000 and 2000 cycles per second were discernible over background noise levels. The test information also indicated that the noise level associated with dropping and dragging metal containers over all surfaces were far higher than the respective noise levels created by disposable bags.

2. Fly Studies. A study of fly generation in household solid waste bags at the City of Inglewood was conducted in cooperation with the Department of Public Health of the State of California.[8] The following excerpt is taken from the State report of the study.[10]

"Studies in many communities in California . . . have indicated that excessive numbers of green blow flies (*Phaenicia cuprina* and *Phaenicia sericata*) are produced in refuse containers with once-a-week refuse collection at homes without garbage grinders . . .

"Green blow flies have a life cycle that is well suited to once-a-week refuse collection. The adult female enters the refuse container and lays 50 to 200 eggs. In warm weather these eggs hatch in the refuse container for four or five days. They then crawl out of the refuse container in order to enter the pupal stage in the soil. About ten days later the adults emerge from the pupae and start another generation of flies. Once-a-week refuse collection allows many larvae to crawl out of refuse containers before the refuse is collected . . .

"The data obtained during this study demonstrate that the existing once-a-week refuse collection in the City of Inglewood is not adequate to prevent the production of green blow flies. The use of polyethylene liners in the containers did not substantially reduce the magnitude of fly production. Analysis of the data, based on the total number of larvae collected and the number of containers with or without polyethylene liners . . . the amount of fly production was not reduced enough by use of the polyethylene liners to warrant their recommendation for fly prevention."

Numerical data on the number of larvae migrating from solid waste containers is presented in Tables 26 and 27.[8] The data is quite variable, both from container to container and from week to week from the same container. Frequently a few containers with high fly production accounted for a high proportion of the total fly production in a given week. The old dirty cans that contained the polyethylene bag liners probably functioned as a major fly source. Fly control would be assisted by using containers with open bottoms to hold the liners.

Bactericides and odorous animal repellants were investigated for use on conventional containers and impregnation of bag materials. Only one bag manufacturer contacted, Mobil, supplied a bag impregnated with animal repellant, the Mobil Keepaway. Bag failures due to animal damage were generally reported less often for polyethylene than for paper bags; no consistent difference in animal damage was reported, however, on Questionnaires 2, 3, and 4 between the Mobil Keepaway and other polyethylene bags (see Tables 46, 47, and 50) and paper bags. The use of the bactericides and odorizers was found to be impractical for cans, and of no discernible usefulness for reducing bag failures caused by animal damage.

3. Litter Index Studies. Five series of observations were made on selected streets in the City of Inglewood to determine the extent of littering. On each selected street, a 1,000 sq ft area, 200 ft long and 5 ft wide, as illustrated in Figure 29, was observed. The litter items in such area were collected, identified, and dimensionally measured. Thirty-six streets were observed, located in the demonstration areas B3, B4, C5, C6, and the Briarwood condominium.

A "litter index" was defined as the sum of surface areas (one side only) of all readily visible pieces of litter in a 1,000 sq ft test area. A tabulation of these indices, together with their respective streets, is given in Table 28; the test areas may be located in Figures 3, 4, and 5.

The litter found in areas using bags and cans is presented in Table 29. The mean litter index for the can routes was 71.6 which was almost double the 40.3 index for the bag routes. The average number of items for the bag routes was 4.1 and for can routes 6.1.

The litter index ranged from 0 to 244.8 sq in. of litter surface per 1,000 sq ft of ground area. The mean value was 46.0. The litter index in the Briarwood condominium area, 1 sq in. per 1,000 sq ft, was significantly less than that in the other areas, with four of the six test locations having no litter at all. Excluding the Briarwood condominium area, the average litter index was about 55. The individual litter most frequently found were paper, match books, cigarette packs, facial tissues, and candy and gum wrappers. Plate 2D shows a typical collection of litter. Litter was observed immediately after solid waste collection in four test areas. The collectors usually cleaned up litter they deposited.

The distribution of litter item surface area (one side) is shown in Figure 30. It was found that the greatest number of litter items had surface areas in the ranges of 2 to 3 sq in and 10 to 20 sq in. The distribution of litter by maximum dimension is shown in Figure 31. The greatest number of litter items had maximum dimensions ranging from 1 to 5 in.

Eight observations were made for container spills at collection stops. On can routes a total of 51 spills were observed which amounted to 3.5 percent of 1,457 stops surveyed, and 0.9 percent of the 5,427 cans observed. A total of 11 spills were observed on bag routes which amounted to 2.39 percent of 461 stops and 1.2 percent of 919 bags observed. Bag closure ties were used on 61.8 percent of the bags observed on all three bag routes. On the three can routes, 41.5 percent of the cans observed were covered.

4. Safety. The hazards encountered in carrying heavy containers and when stepping onto or off of collection trucks are reflected in the results of a California study[11] which indicated that one in every two lost-time injuries reported in solid waste collection work was due to strain, sprain, or dislocation. In comparison, only about one-third of all reported disabling injuries in California industries, taken as a group, were attributed to strains, sprains, or dislocations.

Back strains represented the leading type of injury reportedly sustained by waste collectors; they accounted for about one-fourth of the injuries recorded. Sprained ankles were also recorded more frequently for waste collectors than for industrial workers as a group. Cuts, lacerations, and punctures accounted for 14 percent of collectors' lost-time injuries; this percentage was somewhat less than that of other industrial workers. The use of heavy duty work gloves has helped reduce this type of injury to waste collectors.

More than half of the lost-time injuries occurring in waste collection during the six month period studied in 1967 resulted from handling metal or other hard cans. Two out of every three lost-time strains or sprains in collection (including most injuries to the workers backs, necks or trunks) occurred while handling cans. Frequently the employee strained and injured himself when he made a sudden or awkward movement to avoid dropping a can or in attempting to push or pull a can that was unexpectedly heavy or too unwieldy to be lifted by one man without assistance. About 43 percent of all slips and falls during collection occurred when the injured employee handled a can. Workers frequently slipped when lifting cans for emptying into the truck or into the collector's carry can. Some workers slipped or fell while carrying cans down wet or littered walk-ways, or they tripped over sprinkler heads.

Collectors occassionally dropped carry-cans or householder's cans on their feet or caught their fingers on the jagged edges of metal waste cans. Safety precautions to protect feet and hands should be stressed. Some of the hazards faced by waste collectors arise from the following: sharp objects placed in containers;

loose broken glass; chunks of concrete or other heavy objects covered with paper or other trash; garden hoses or other impediments strewn along the pathway to the can; and defective rusted cans with unserviceable handles.

During the conduct of the two-year demonstration study, no injuries to collectors were reported as a result of bag handling on the bag demonstration routes. Two injuries to collectors were recorded during the same time, however, on the conventional container (can) routes; one sprained shoulder and one cut hand. Disposable bags can significantly reduce work hazards for the collector because of the following characteristics:

a) Bags have a limited weight load capacity. Unless very carefully loaded and handled by the householder, bags containing more than 40 to 50 lb weight would be unlikely.

b) Conventional metal containers add materially to the total weight handled by the collector. Table 10 indicates that typical galvanized metal cans of the 32 to 40 gal size have a tare weight between 8 to 12 lb each. This represents about 1/3 of the average total weight of a can plus contents.

c) Jagged edges of metal containers would be eliminated.

d) Dust particles and pathogenic organisms in the air would be reduced.

e) Noise levels are lower.

Detrimental effects of bags are that they provide little protection for the collector from sharp waste objects such as broken glass, or rose bushes. Occasionally, during the vehicle compaction cycle, tightly-packed polyethylene bags may explode and scatter contents onto the collector.

C. Handling and Disposal Operations

1. Effects of Polyethylene Bags on Landfill Procedures. The solid waste from the City of Inglewood is delivered for disposal to the Los Angeles County Sanitation Districts' Mission Canyon Landfill. In 1970, the landfill reportedly handled a total of approximately 5,000 tons of waste each day. About 175 tons per day originated in the Inglewood municipal system.

An interview sheet (Appendix E6) was distributed to field operators at the Mission Canyon Landfill Site. Responses from four operators ot crawler tractors on site and comments from the foreman in charge of the landfill operations were noted; these responses and comments were concerned with operating problems which arose due to the disposal of solid waste contained in polyethylene bags.

The results indicated that polyethylene bags improved operations at the landfill disposal site. Three of the four field operators reported better pushing of the solid waste, and two reported an improvement in the spreading operations; in the case of landfill compaction of solid waste, the operators reported that the bags had no effect. From an environmental standpoint, all operators reported reduced blowing of solid waste and dust, while two operators also indicated a reduction in odor.

Discussions with the Landfill foreman indicated that the polyethylene bags have caused some problems during rainy weather when the bags tended to lodge between crawler tracks and the frame of the bulldozer. It was also indicated that the bags made smooth grading on the final landfill solid waste compaction at the fill site more difficult. As indicated by the operators, the foreman reported bags of solid waste were more easily handled by a bulldozer than the unbagged wastes.

2. Polyethylene and Paper Bag Bio-Degradation Effects. In common with many plastic materials, polyethylene is not readily bio-degradable, and its disposal in sanitary landfills does not result in rapid alteration of its physical properties. Therefore, the effect of widespread use of polyethylene bags as solid waste containers on the proportion of plastic in present day solid waste was considered.

The ratio by wet weight of an empty polyethylene bag to its weight when filled with waste was on average less than one percent. This may be compared to the total of two percent by wet weight of plastic material generally present in domestic waste. Polyethylene bags would, therefore, increase the amount of plastics in domestic solid waste about 50 percent by wet weight. Domestic waste normally comprises less than one-third by weight of all solid waste generated, with the remainder generated from commercial and industrial sources. The contribution of polyethylene bags to the total wet weight of solid waste in a landfill, therefore, would be less than one-third of one percent. The total effect of polyethylene bags on pollution problems at disposal sites would be negligible since their non-biodegradable nature would produce no contribution to groundwater pollution. The combustion by-products from polyethylene are carbon dioxide and water, which should not cause significant air pollution.

Paper bags treated with waterproof resins may temporarily resist bio-degradation but would have little total environmental impact on landfill or incineration disposal.

3. Effects of Disposable Bags on Transfer Station Operations. During one period of the two-year demonstration program, collection trucks were diverted to a nearby waste transfer station. The transfer station was of the raised ramp type wherein collection trucks dumped their loads from a higher elevation into a large receiving transfer trailer parked at a lower elevation. Because of the short test period, no quantitative measurements were made; however, staff project engineers qualitatively observed that the waste transfer station operations were generally improved. There were reductions in dust and blowing litter resulting from the transfer of the bagged waste, even though many of the polyethylene and paper bags were ripped during the compaction and unloading processes.

Visual comparisons of the volume occupied by the bagged and normal solid waste in the transfer trailers indicated there were no substantial differences.

4. Effects of Disposable Bags on Packer-Type Collection Vehicle Waste Density

The number of collection vehicle loads (trips to landfill) collected per day and packer vehicle densities were obtained from all three routes before and after bag distribution. The number of vehicle loads collected on bag routes versus can routes is given in Table 72. Generally one or slightly more than one truck load was collected each day on each route. The densities achieved by the packer vehicles for bag and can routes are given in Table 72. No significant differences in packer vehicle waste densities were found at the 2.5 percent level.

D. Field Demonstration of Liners for Large Containers

A limited number of 2 mil polyethylene liners were specially fabricated for testing in waste bins of 2 cu yd and 3 cu yd capacity. These liners were distributed for a period of three months to some 21 restaurants located in Inglewood and serviced by contracted private waste collectors. The locations of the demonstration restaurants are shown in Figure 32. The restaurant bins were cleaned, or replaced if deteriorated, prior to using the liners.

A field survey was made of a number of these restaurants to investigate the major problems encountered in using the liners. The information gathered by the field survey team was used to draw up a questionnaire which was distributed at the end of the three month period to all the restaurants taking part in the demonstration. A copy of this questionnaire is included as Appendix E7. A time and motion study was made to determine the effects on collection time resulting from using bin liners.

1. Results of Field Survey. The major problems reported by the restaurants testing the bin liners were as follows: (1) four users stated the liner sometimes slipped off the bin lip and collapsed; (2) one user indicated that the liner often did not fall out of the bin when it was emptied; and (3) one commented that the liner was troublesome to handle. Plate 2B shows a bin with a liner which had slipped off the bin. One user tied the liner corners to the bin to keep it in position. One reason the liners did not hold well to the bin rim was that the bin lid hinges normally ran the entire side length of the bin, thus eliminating this lip for gripping. Three users stated that no problems were encountered. The positive results reported with bin liner usage were: (1) the bins were cleaner; (2) odors were reduced; and (3) flies were reduced.

2. Results of Bin Liner Questionnaire. A summary of the questionnaire responses is given in Table 30; additional comments are given in Table 31. The results, of the questionnaire substantiated the findings of the field survey. Improvements were noted in fly and odor problems and a particular improvement was noted in bin cleanliness, which would result in a reduction in frequency of bin cleaning. Six of the fourteen

respondents reported difficulty in installing the liners. Comments made by the respondents indicated this was due to the liners being too small, although it seems more probable this was due to non-uniformity of bin size; also, the positioning of lid hinges on the bin may have contributed to the problem. Other comments received indicated that two people were needed to install a liner, while one respondent suggested that the liner installation should be carried out by the collector. The successful reception given the bin liner system may be directly measured by the unanimous approval of the responding users and their recommendation for continued use.

3. Time and Motion Studies of Bin Liner Collection. Field studies were completed during collection to evaluate bin liner effects on truck pickup efficiency. The work task movements involving only the liners was timed. The average times for each task are given in Table 32 for bins with and without liners.

The time required to perform collection tasks with the liner was slightly greater than the time required to perform the same tasks when liners were not present. Additional work was required to unhook the liner; this accounted for nearly half the time expended at a truck loading stop. There were also slightly greater dump and lowering times with bin liners.

4. Bin Liner Cost Evaluation. Estimates of collection time with and without liners shows an increase of 0.232 minutes per bin serviced (see Table 32). A cost analysis for the bin liners is presented in Table 33. The total cost savings attributable to using bin liners is about $26 per bin per year and results from a reduction in cleaning cost and an estimated 50 percent increase in the depreciation period. These savings were more than offset by the cost of the liners ($117 per restaurant per year) and the increased collection time cost $14 per year). These costs do not include the liner installation costs which were assumed to be absorbed by the restaurants. The net increase in yearly cost of about $105 per restaurant for using the liners does not appear to economically justify their use under Inglewood demonstration conditions.

E. Survey of Continued Bag Use

Follow-up surveys were conducted in Study Areas B4 and C5 after the demonstration bags were used up to evaluate public acceptance of polyethylene and paper bags. The surveys, completed over a six-month period, consisted of monthly counts of residences voluntarily using bags. The results are presented in Figures 33, 34, and 35. The use of paper and polyethylene bags has greatly decreased since the residents had to begin purchasing their own bags. The 1.5 mil commercially-available polyethylene bags are apparently replacing the demonstration's specially-purchased and more expensive 2.5 mil polyethylene bags. There was little difference in overall bag usage trends at single family residences or multiple dwelling units (apartment buildings). Bag usage data for apartments and single unit residences is presented in Figure 35. Apparently, all users discriminated between bag systems largely on the basis of costs. The total polyethylene bag use trend in Study Area B4 was downward until July. During June, two major department store chains began advertising 1.5 mil polyethylene waste bags in Inglewood newspapers. The residents evidently responded to the advertising as indicated by the increase in 1.5 mil polyethylene bags illustrated in Figure 33. The paper bag use in the same study period and test areas dropped to less than 5 percent of the total dwelling units.

VII. PUBLIC HEALTH STUDIES

A. Microbiological and Dust Tests

1. Parameters. It would be expected that when using bags, dust emission to the environment would be reduced. The improved sanitary conditions should benefit not only the total environment but also the waste collector. In order to define the extent of the dust problem, a study was designed to measure the amount of dust generated during collection of both bags and cans.

After experimentation with various dust test methods, it appeared that exposing bacteriological plates containing brain heart infusion agar, an appropriate incubation media, would be the most suitable method for measuring dust levels. The decision was based on the assumption that each dust particle would contain some bacteria and that a colony of bacteria could grow around each incubated dust particle. Incubated bacterial colony counts would therefore give a measure of the quantity of dust generated and also allow specific bacteria and fungi to be identified further if desired. Parameters that were considered when designing the test included the following:

a) Waste collection activity to be sampled.

b) Dust collection bacterial plate exposure time.

c) Point of dust sample collection.

d) Number of dust samples.

e) Background dust conditions.

These parameters and the reasoning behind the study methods are described below.

a. Waste Collection Activity to be Sampled. The collection activity when maximum dust generation occurred was selected for critical study. This occurred when the collector dumped the can waste into the truck hopper. It was also determined that during this period the collector was exposed to the most dust. In a few instances when the truck compaction plate used to compress material in the hopper was activated, polyethylene bags exploded and scattered dust outside of the hopper. The collector was generally some distance from the hopper when this latter phenomenon occurred. The critical dust test period occurred when the waste fell from the hard container into the truck hopper.

b. Dust Collection Bacterial Plate Exposure Time. A 10-second plate exposure time was selected. Observations in preliminary tests revealed that the majority of the dust settled within 10 to 15 seconds. Also, 10 seconds allowed enough time for the collector to empty one can and yet did not delay normal collection.

c. Point of Dust Sample Collection. Various locations for sampling were considered, but locating the dust collection plate exposure points near the collector's face was considered most realistic from the point of health. This location should provide samples corresponding to the collector's "potential" air breathing. Of course, the collector would not inhale all the particles caught on the test plates into his system. The designated collection point was therefore set at the collector's head level, just to either side to be downwind of the collector, and with the collector standing next to the truck hopper.

d. Number of Dust Samples. Preliminary tests revealed that about 25 to 30 plate samples were required to get a representative dust fallout count. This was the basis of the decision to take 30 samples distributed throughout the route of which four would be background samples.

e. Background Dust Condition. Background samples were taken at various times along the collection route with the standard plate exposure time of 10 seconds. The background sample locations were 15 feet or more away from the waste collection truck. Care was taken not to take samples during windy periods or other abnormal test conditions.

2. Field Tests. A series of dust sampling tests was performed on January 7, 1970 to obtain dust counts during the collection of domestic solid waste from cans. Some 30 bacteriological dust samples were obtained, four of which were background, in accordance with the aforementioned procedures. Specific data is tabulated in Table 34.

Another series of tests was run on January 27, 1970 to determine dust counts with bags. Again 30 plates were exposed, four of which were background samples. Only those collection stops at which bags were predominantly used were chosen for the tests. Specific data is tabulated in Table 35.

Laboratory tests were made on the two sets of samples, as described in Appendix F.

3. Bacteria and Fungi Counts

a. Cans. Table 36 lists the total number of bacteria and fungi that grew on brain-heart infusion agar after 24 and 48 hours of incubation at room temperature. Plate numbers 1 through 30 included those exposed for background conditions (Numbers 1, 8, 16, and 30) and those exposed at various times during collecting hard containers full of domestic waste.

i) 24-Hour Plate Count Results

Bacteria Count. Background samples 1, 8, 16, and 30 had dust counts of 0, 90, 70, and 0, respectively, which average about 40. The collection vehicle dust test sample counts ranged from 10 to 1000 per 100 mm diameter plate. The dust count average for the collection vehicle samples was 164 per 100 mm diameter test plate as compared to 40 for the background.

Fungi Count. Background samples had no fungi colonies. The collection vehicle counts ranged from 0 to 800 fungi per 100 mm diameter test plates with all but one exceeding the background count. The average collection vehicle sample count was 81 per 100 mm diameter test plate.

ii) 48-Hour Plate Count Results.

Bacteria Count. The four background samples had bacteria counts of 1, 160, 70, and 20 and averaged 63 per 100 mm diameter test plate.

Some of the collection vehicle samples were uncountable due to massive bacterial growth during the 48 hours incubation. For these samples an extrapolation was made based on the 24-hour counts and an average growth rate calculated from the bacterial growth of other known samples.

Collection vehicle 48-hour bacterial sample counts ranged from 15 to 2500 per 100 mm diameter plate (extrapolated). The dust counts of all collection vehicle samples exceeded the lowest background sample count. Some 73 percent of the collection vehicle dust counts exceeded the background average, and 46 percent exceeded the maximum background count. The samples averaged 389 per 100 mm diameter test plate (including extrapolated values).

Fungi Count. Only one of the four background samples showed fungi colonies and it had 2, giving an average of 0.5.

Collection vehicle dust sample counts ranged from 0 to 2600 per 100 mm diameter test plate (extrapolated) with 96 percent exceeding the background values. The samples averaged 249 per 100 mm diameter test plate (including extrapolated values).

b. Bags and Liners. Table 37 is a tabulation of a 100 mm diameter test plate count results. Samples 1, 10, 20, and 30 are background samples and the balance are collection vehicle dust samples.

i) 24-Hour Plate Count Results.

Bacteria Count. No bacteria colonies appeared on background 100 mm diameter test plates. Regular collection bag work period samples averaged 1.4 colonies per 100 mm diameter test plate with 12 of 26 plates (or 46.2 percent) containing colonies.

Fungi Count. No fungi colonies were found on the background samples. Regular collection bag work period samples averaged 0.15 colonies per 100 mm diameter test plate. Only two plates, or 7.7 percent, indicated the presence of colonies.

ii) 48-Hour Plate Count Results

Bacteria Count. No colonies developed in the background samples. Regular collection samples averaged 8.1 colonies per 100 mm diameter plate, with 92.3 percent of the samples having counts exceeding the average background count.

Fungi Count. One colony was counted in the four background samples giving an average of 0.25 per plate. Collection vehicle samples averaged 21.7 colonies per plate. The fungi count of twenty-six samples (or 92.3 percent) exceeded the average background count.

4. Summary of Microbe Counts. Table 38 is a summary of results for the plate count studies using cans and bags as waste containers. Microbe counts were affected little by background conditions; thus for comparison purposes it can be assumed that the background bacteria counts for cans were the same as for bags, i.e., zero at both 24 and 48 hours and with the same growth rate as indicated in the first test series. Under this latter assumption, can values of 124 and 326 bacterial colonies per 100 mm diameter plate for the 24 and 48-hour counts, respectively, were obtained. In comparison, 1.4 and 8.1 bacterial colonies per 100 mm diameter plate for 24 and 48-hour counts, i.e., 98 to 99 percent less bacteria and dust was found with bags when compared to cans.

Approximately the same reduction was indicated for fungi counts. With cans the averages of fungi colonies per 100 mm diameter plate were 81 and 249 at 24 and 48 hours, respectively. Counts with bags averaged 0.15 and 21.7 colonies per plate at 24 and 48 hours, indicating about 99.8 and 91.3 percent less fungi with bags. The comparison of fungi counts is specific since in both test series the fungi background values were essentially zero. Assuming that the number of microbes which developed on a media plate exposed to dust is a measure of the quantity of dust in the air at that point, it was found that a change from cans to bags for waste containers reduced dust generated during waste collection by more than 90 percent.

5. Microbiological Identification. This analysis was concerned with identification of specific bacterial and fungal types encountered in the dust of domestic solid wastes, and also with isolating pathogens causing infections and diseases. No attempt was made to identify the microorganisms in the second series since it was anticipated that most of them would be the same as those found on the first series; i.e., members of the genera Aspergillus, Penicillium, Bacillus, and gram negative bacteria. Due to the relatively low number of colonies on the test plates exposed during bag collection, the analysis was carried out primarily from the plates exposed during can collection.

a. Bacteria. Bacterial colonies on the background plates were of the genus Bacillus, which are large, gram positive, aerobic, spore-forming rods, and genus Staphylococcus, which are spherical cluster cells. The only isolated species which is highly pathogenic is *Bacillus anthracia*, which is the cause of anthrax; it is hard to distinguish this from many other species of aerobic, spore-forming bacilli, except on the basis of pathogenicity. The most commonly encountered saprophytic species were *B. subtilis*, *B. megaterium*, and *B. cercus*; *B. subtilis* may occasionally cause human eye infection sometimes complicated by septicimia.

In contrast to the background plates, the test plates showed a wide variety of fungi and bacteria both chromogenic and achromogenic. The domestic solid waste samples harbored various pathogenic, morphologically different, viable bacteria, as can be seen from Table 39 which lists the morphological features and genus of a few bacteria isolated from representative test plates taken during can collection.

Occurrence of gram positive hemolytic bacteria on test plates indicated the possible presence of pathogens in the dust samples. These organisms could enter the body via the respiratory tract, from the dust in the air. *Streptococcus* and *Diplococcus* could cause such respiratory diseases as scarlet fever, septic sore throat, endocarditis, tonsillitis and lobar pneumonia. Members of the genus *Staphylococcus* can cause both localized and systemic infections such as carbuncles, boils, osteomylitis, and septicimia.

The gram negative rods usually appear as relatively large shiny gray colonies which may or may not be hemolytic. These bacteria are able to grow at low pH, in the presence of bile, and under anaerobic conditions. Gram negative rods of pathogenic nature include: *Vibrio comma*, responsible for cholera; *Salmonella*, responsible for typhoid and paratyphoid fevers: and *Shigella* for bacillary dysentary. Differentiation of these genera was not made because of the extensive biochemical and immunological analyses required. A few members of gram negative *Protens* and *Klebsiella* are pathogens. *Pseudomonas* is generally considered nonpathogenic, but is sometimes found in a variety of pus-forming conditions, and in some cases it may be the major cause. Similarly, some strains of *Escherichia* have significant pathogenicity.

There are many other gram positive and negative, rod-shaped, spore-forming bacteria which are slow-growing and pathogenic. Such bacteria may have been present in the dust but did not grow on the test plates because the plates were overcrowded by other fast growing microorganisms. Examples of such slow growing bacteria are: *Comebacterium*, which causes diptheria; *Mycobacterium*, which causes tuberculosis and leprosy; *Brucella*, which causes undulant fever; and *Hemophilus*, which causes respiratory infections. A number of these bacteria are known to be present in dust, plants, and soil, but none were identified during the study.

b. Fungi. Fungi are heterotrophic multicellular members of the plant kingdom and are referred to as thallophytes. Of about 50,000 species of fungi, only about 50 are known to cause infectious diseases in man. Some are obligate parasites on man. Table 40 lists a few genera of fungi encountered during the present investigation.

Almost all the genera are common saprophytes and are soil inhabitants. The only exception is Microsporium. This is well known dermatophyte of humans and animals. Although Aspergilli are among the most common fungus, several strains are pathogenic and may produce either inflammatory or chronic granulomatous lesions in the bronchi or lungs, often with hematogenous spread to other organs. Aspergillus fumigatus is the species most frequently associated with pathogenic processes. This may include pulmonary aspergillosis of a severe and invasive type. Phycomycosis is a fatal disease caused by members of the class Phycomycates, which produce aseptate mycelia and are ordinarily considered nonpathogenic fungi. The genera involved include Mucor, Rhizopus, Absedia, and others. The fungus enters the nose of susceptible people, particularly uncontrolled diabetics and patients receiving prolonged antibiotic, corticosteroid, or cytotoxic therapy, and penetrates the arteries to produce thrombosis. Later it invades the veins and lymphatics, producing infarcts. The disease assumes cerebral and pulmonary forms and, rarely, intestinal, ocular, and disseminated forms.

c. Yeasts. The yeasts are single-celled nucleated microorganisms, reproducing primarily by budding. In the vast majority of cases, yeasts are considered to be saprophytic and are used in the wine industry because of their ability to ferment carbohydrates to alcohol. There are a few yeasts which are pathogenic and cause chronic diseases in man. Table 41 lists the major diseases caused by yeast-like microorganisms. Usually infections caused by yeasts are deep-seated systemic diseases. They are particularly difficult to treat since there are, at present, no really adequate agents effective against them.

6. Evaluation. The dust generated during collection of domestic solid waste contains a large number of bacteria and fungi of different genera. Methods to reduce the efflux of these microorganisms to the atmosphere would benefit both the collector and the environment. The presence of pathogenic bacteria and fungi is possible based on the genus families identified, but no pathogenic species were identified in the samples analyzed. The genus discussed are often present in the type of dust found in domestic solid waste.

A bibliography on related bacteriological dust studies is presented in Appendix G.

B. Laboratory Dust Distribution Study

1. Objective. The objective of the laboratory dust distrubution study was to investigate the extent of dust scatter when loading a collection vehicle with solid waste from can containers.

2. Facilities and Equipment. Facilities and equipment consisted of the following: a box 2 ft x 2-1/2 ft x 3 ft to simulate a waste hopper on a collection vehicle; a 40-gallon waste container; simulated waste consisting of 90 percent by wet weight dust and dirt from a vacuum cleaner; 15-47 mm disposable sample Petri dishes (Millipore), containing a grid filter paper; a stop watch for timing; and an enclosed clean room test area.

Vacuum cleaner dust is the most common type of dust found in domestic solid waste. The high (90 percent) dust content was used to assure that there would be sufficient dust to obtain an accurate record of its distribution. The controlled conditions (windless) were used because it was not feasible to simulate wind conditions due to their great variability.

3. Procedure. It was assumed that during the solid waste container emptying operation the dust produced would distribute itself in a pattern with the center of the hopper as a point of maximum concentration. The pattern of dust distribution for windless conditions was defined by placing clean Petri dishes with appropriate filter papers on the floor of an enclosed area at selected distances from the hopper to catch the dust fallout. The density of collected dust particles were then determined from four test runs in the laboratory and the results plotted as dust particle concentration contours.

The tests were completed as follows:

a) All equipment including the solid waste container filled with simulated waste was taken to the clean room test area where an essentially windless condition was maintained.

b) The solid waste "hopper" box was placed at the desired dumping location and level.

c) Fifteen covered Petri dishes were placed radially from the center of the hopper for each test run. One set of five Petri dishes was placed in line with the dumping direction on the opposite side of the hopper. Another line of five dishes was placed at a 45° angle from the first line and the remaining five dishes were placed 90° from the first. Hence, coverage was obtained for the quadrant of a circle with the hopper as the center. Plates were placed at 3 ft, 4-1/2 ft, 6 ft, 9 ft, and 12 ft from the hopper center on each radius line.

d) Prior to dumping the can container, the Petri dish covers were removed and numbers assigned each dish to define its position.

e) The can was emptied so that the solid waste was dumped into the "hopper" box.

f) The resulting dust was allowed to settle for 2 minutes and then the Petri dishes were re-covered.

g) The Petri dish samples were then taken to the laboratory and the number of dust particles per square inch determined using a 50X microscope. Only individual particles were counted and no differentiation was made as to particle size. The particle density was calculated for several (3 to 10) grid areas of each plate and averaged to get an overall plate density in particles per square inch.

h) The dust concentrations at each Petri dish location were then plotted on a map of the laboratory test area. Dust concentration contours were drawn by connecting points of equal particle concentration constructed by interpolation of particle counts at each Petri dish location along the three radii.

4. Results. Figure 36 is a plot of dust concentration contours for the waste can collection simulation. The entire pattern was skewed along the direction of dumping. An area of maximum concentration was located 4-1/2 feet from the hopper center in the direction of dumping. This high density dust area was in addition to the hopper area directly under the dumped waste. Dust concentrations ranged from 77,500 particles per square inch at 4-1/2 feet to 500 particles per square inch at a distance of about 13-1/2 feet from the center of the hopper in the direction of dumping. Ninety degrees to the right of the dumping direction at about 10-1/2 feet from the hopper center, a level of 500 particles per square inch was observed.

It is interesting to note that the dust concentration drops off between point M and point D (Figure 36). This was probably due to the shielding effect of the hopper sides which intercepted the dust particles.

VIII. QUESTIONNAIRES

A. Distribution of Questionnaires

The questionnaire survey covered bags and holders available from manufacturing during the years 1969 and 1970. The questionnaire tabulations present relative comparisons between two or three bag systems used by any one household. The summary compares the overall results in relative terms and is not to be construed as an absolute rating comparison.

1. Questionnaire I (Pretest Questionnaire). To evaluate citizen interest in bags, public opinion surveys were undertaken prior to the demonstration tests. Information was sought regarding the expressed needs of the public in waste collection service. The questionnaire was pretested by personal interviews prior to being distributed to residents in the three study areas in 1968. It was designed to permit the resident to indicate his level of satisfaction with the pre-demonstration collection system in Inglewood, and also where emphasis should be placed in making desired improvements. A copy of the pretest questionnaire is included as Appendix E1.

2. Questionnaire 2. During the first bag distribution, the following five bag systems were studied in the field to determine public acceptance and use characteristics:

a) Mobil Keepaway and Friedman Narrow Polyethylene Bags (2.5 mil) with Holders,

b) St. Regis Paper Bag with Holder,

c) International Garbax Paper Bag with Holder,

d) Friedman Wide Polyethylene Can Liner (3.0 mil), and

e) St. Regis Paper Bag without Holder (free-standing).

Following 3 months of field use, Questionnaire 2 was mailed to the users in Areas A1, B4, and C5 to evaluate their experiences with the bag systems. A copy of this questionnaire is presented as Appendix E2. The number of questionnaires returned, classified according to bag system and residence type, are presented in Table 42. Due to the similarity in the dimensional and physical properties of the Mobile Keepaway and Friedman Narrow polyethylene bags, all responses to Questionnaire 2 were notated as the Mobil Keepaway bag, and any results obtained on the performance of the Mobil Keepaway bag may be taken as to also apply to the Friedman Narrow bag.

3. Questionnaire 3. In July 1969, a second bag system distribution was made so that Areas B4 and C5 users could make a firsthand comparison of two systems. The only alterations made in bag type were the use of 3.5 mil Wagner can liners in place of the 3 mil Friedman Wide can liners and the discontinuation of the Friedman Narrow bag. Questionnaire 3 was sent out to residents in Areas B4 and C5 after the completion of the second 3-month test period. A copy of this questionnaire is provided as Appendix E3. The questionnaire responses, classified according to the bag system utilized, are presented in Table 43.

Questionnaires 2 and 3 were similar with the following exceptions: the question on the difficulty of placing polyethylene liners in cans, and a question on whether the user found it necessary to continue use of conventional containers, were not repeated in the second questionnaire. Also, a group of questions to compare one disposable system to another, and a bagging system preference were added to Questionnaire 3. Responses to both questionnaires were separated for analysis into two categories; those from residents in single family homes, and those from apartment dwellers. With each questionnaire the total response of both single family and multiple family residents were combined for analysis. A detailed review of Questionnaires 2 and 3 was made on the basis of these combined responses, except where apartment residents responded in a significantly different manner than the private residents; in several cases, apartment residents omitted responses to a particular question. Lists of the responses to Questionnaires 2 and 3 are presented as Appendix H; Tables H1 and H3 are expressed in number of responses, and Table H2 and H4 are given in percentages of responses.

A combined summary of the results of Questionnaires 1 and 2 is presented later in the text.

4. Questionnaire 4 (Briarwood Condominium Questionnaire). Three bag systems were distributed to the residents of Briarwood condominium. The systems tested were:

a) Mobil Flamegard Polyethylene Bag (2.5 mil) with Holder,

b) St. Regis Paper Bag with Holder, and

c) International Garbax Paper Bag with Holder.

The object of the questionnaire was to obtain further comparisons on the performance of the bag systems in an area where the bags would be carried to the collection vehicle by the collector. A copy of this questionnaire is included as Appendix E4. The Mobil Flamegard bag was essentially the same bag as the Mobil Keepaway; it had the same thickness (2.5 mil) but a slightly larger capacity.

5. Questionnaire 5 (Follow-Up Questionnaire). This questionnaire was distributed to the residents of Inglewood in June 1970, three months after termination of bag use in Area A, and six months after using various bag systems in Areas B and C. It was the final householder questionnaire to obtain the overall reactions of the residents to the introduction of the bag systems after they had an opportunity to use several configurations. A copy of this questionnaire is presented as Appendix E5.

B. Results of Questionnaire 1 (Pretest Questionnaire)

Table 44 summarizes the results from the completed questionnaires. Responses from 886 residences out of 1,600 questionnaires mailed was more than 55 percent.

The questionnaire response indicated that changing to a bag system would result in few apparent benefits. Only 29 percent expressed inconvenience in returning emptied conventional hard containers from the curb to the household storage locations and 71 percent indicated this was never inconvenience for them.

Many residents commented on the satisfactory collection service provided by the City. Over 75 percent of the respondents judged the pre-demonstration system as fair to excellent. Less than 1 percent indicated service was poor. The remaining 24 percent of the comments amplified answers to one or more of the questions contained in the questionnaire. In general, the citizens were satisfied with the pre-demonstration collection service.

The question may be posed that since the great majority of the area residents were satisfied with the level of service, why should collection system improvements be made? The answer relates to public service needs. Unless conditions of sanitation are grossly inadequate, the public generally becomes accustomed to and accepts existing service standards. The public is normally unaware of possible higher level service improvements until they are exposed to them. This probably explains the public acceptance of new products following trial use and the current practice of vendors mailing free samples of all types of products to the public for promotional advertising. The influence of news media and the impact of community leaders, accustomed to achieving higher service levels, also helps promote general public acceptance for improved solid waste management.

C. Results of Questionnaires 2 and 3

The questionnaires were analyzed primarily to observe the overall effects of the use of bags as solid waste containers in place of metal or plastic cans, and secondly to compare the performance of the five types of bag systems under test. The distribution of the two questionnaires allowed a determination of both the initial response to the introduction of the bags as well as direct comparisons to be made between different bag systems.

The summaries of responses from both questionnaires were combined in Table 45 in order to give the overall reaction to the bag systems. These responses, expressed as percentages of the number of questionnaires returned, are given in Table 46.

1. Improvements. The greatest improvement noticed by the respondents was the impact of the bags on neighborhood appearance both on collection day and during normal usage; the most popular of the bag systems were the St. Regis paper bag with holder and the polyethylene liners. In general, it was felt that the bags were far more attractive than the conventional cans, as illustrated in Plate 3.

A sharp decrease in collection noise and fly problems were reported. Odor conditions and spillage were also reduced for all the bag systems, with the exception of the St. Regis paper bag used without a holder; the number distributed of this latter type of free-standing bag was relatively low, and therefore the results may not be representative.

2. Difficulties. The most widespread difficulty encountered with the bags was in closure, with the Mobil polyethylene bag and St. Regis paper bag without a holder causing the greatest problem. The field studies indicated that the latter bag tended to be overfilled, and thus the bag mouth resisted closure.

Some difficulties were reported in mounting the three bag types on holders. The Mobil bag and holder caused some difficulty when placing solid waste in the bag. Mobil developed an improved (1970) holder which overcame most of the lid opening and bag filling problems present in their original (1968) design and this was used in the Briarwood condominium distribution. Difficulties experienced with the International and St. Regis holders were negligible. Carrying the bags to the curb for collection was reported as a problem with the polyethylene liners and to a smaller extent with the International paper bag; but generally the respondents reported that transport of the bags was far easier than carrying cans.

Sharp objects were reported as the main cause of failures for the Mobil polyethylene bag and the can liners. The most common cause of failure for both the International and St. Regis paper bags was the presence of wet solid waste. Animal attack caused some failure with all types of bags, especially in the case of the 2.5 mil Mobil polyethylene bag, as did deposition of heavy refuse. Reported failure due to rough handling was negligible.

The overall success of replacing cans with bags as solid waste disposal containers was indicated by the total favorable response of 77.8 percent of the householders who preferred the bag system to conventional containers. The most popular of the five bag systems used were the polyethylene can liners (86.5 percent favorable) and the St. Regis bag with holder (82.0 percent favorable).

3. Comments. A summary of questionnaire comments is presented in Table 47. The three characteristics of the bag systems which residents liked the most were: (1) cleanliness; (2) not having to carry cans: and (3) better neighborhood appearance.

The three items which the residents disliked the most were: (1) difficulty of bag closure; (2) problems with packing solid waste such as yard trimmings in the bags, i.e., compacting branches, shrubbery, and other sharp objects; and (3) bag damage due to animals. Residents also expressed concern about the cost of bag systems.

4. System Comparisons. Table 48 was derived from the responses to Questionnaires 1, 2, and 3. The attributes delineated on the left hand column of the table were those on which residents were requested to indicate preferences. The data from the questionnaires was converted mathematically to a scale of 0 to 10 with positive comments being given a maximum value of 10 and negative comments given a minimum value of 0. For each attribute and each system, two numbers separated by

a slash are shown in the table. The right-hand number denotes the residents' comparison of the indicated bag system with the first bag system distributed to them earlier in the test series. The St. Regis paper bag system was rated highest by the residents both with respect to cans and other bag systems. However, the differences in ratings are not great enough to be of significance.

D. Results of Questionnaire 4 (Briarwood Condominium Questionnaire)

The Briarwood questionnaire was similar to Questionnaire 2, which solicited the householders' reactions to bags as solid waste containers, and compared the performance of the three types of bags under test.

A summary of the number of responses to the questions is given in Table 49, and are expressed in percentages in Table 50.

1. Improvements. The analysis of responses showed that the majority of Briarwood householders felt that bags resulted in marked improvements in all areas of solid waste management.

The greatest benefit noted was in appearance; of the 330 residents replying, 226 of them indicated that bags had improved the appearance of the neighborhood on collection day while 241 of them felt that the bag and holder itself was more attractive than the conventional refuse container. Of the three types of bags in use, the Mobil polyethylene and St. Regis paper bags were slightly more popular than the International paper bag.

A marked reduction in collection noise was observed, and more than 60 percent of respondents noted a reduction in spillage and odor problems. Overall, 40.6 percent of the respondents believed there was a reduction in the fly problem. Since the majority of the residences were fitted with screens on both the doors and the windows, a reduction in flies may not be noticeable unless the respondents passed near the waste containers; this may have caused the low response to this question.

2. Bag System Difficulties. The storage of paper bags prior to use was reported as the greatest difficulty. Paper bags are far more bulky than an equal number of polyethylene bags; hence, storage of the latter was simpler. In addition, mounting the paper bags was reported as more difficult than mounting the polyethylene bags. All of the bags produced closure problems with the largest number of difficulties reported with the International paper bag. These closure problems resulted from residents filling the bags too full. The problem might have been rectified by educational literature or further experience with the bag's limitations.

Some difficulty was ascribed to placing solid waste in the bags, and these results correlated with reported difficulties involving operation of the holder lids. In both ratings, the International paper bag system was reported to have caused the most difficulty.

Tipping over of the bag holders was negligible.

The primary causes of bag failure, in the few instances reported, were attributed to sharp objects being placed in the bags. This was particularly evident with Mobil polyethylene bags which punctured more easily than the paper bags; this was corroborated by the polyethylene bag's reportedly higher failure rate from rough handling. Wet wastes reduced the strength of both the International and St. Regis paper bags which caused a few failures. Failure due to heavy refuse and animal damage was reported to be negligible for all bag types.

3. System Acceptance. The individual merits of the three bag types and the overall success of the system in general was indicated by the 79.4 percent of respondents who preferred the bag systems to conventional hard containers. The St. Regis paper bag system, with 82.7 percent favorable response, was the most popular. The Mobil polyethylene 2.5 mil bag system received 79.3 percent approval, while the International paper bag system had a rating of 76.1 percent.

4. Comments. The comments made by the respondents are tabulated in Table 51. The favorable comments indicated a wish to continue with the new system and a desire for knowledge of where to obtain more bags.

The most common negative comments of the residents were a dislike of additional expense for bags and a preference for cans or plastic containers over the bags. These latter comments were probably influenced by the fact that hard plastic containers were supplied free to people who live in Briarwood.

E. Results of Questionnaire 5 (Follow-Up Questionnaire)

The purpose of the follow-up questionnaire for test areas A, B, and C was three-fold: (1) to directly compare the popularity of each of the five types of bag systems after a number of systems had been used consecutively by a householder; (2) to determine the reactions of the householders to the introduction of bags as solid waste containers following a period of continued use; and (3) to obtain a rating of importance on specified bag characteristics on which earlier assessments of bag performance had been based. The response to the importance ratings indicated that many people misunderstood this section. The answers fell into two obvious groupings; one set of responses was related to the importance of the item, and the other responses were related to the problems with bags. The former set of responses was used in Chapter X in the formulation of bag evaluation criteria, and the latter responses were discarded.

Five types of bag systems were studied:

a) Mobil Keepaway and Flamegard Polyethylene (2.5 mil) Bags with Holders;

b) Chase (2.5 mil) Polyethylene Bag with Drawstring;

c) St. Regis Paper Bag with Holder;

d) International Garbax Paper Bag with Holder; and

e) Mobil Luxri (1.5 mil), Friedman Wide (3.0 mil), and Wagner (3.5 mil) Polyethylene Can Liners.

The summary of the responses to the questionnaires is given in Table 52. In general, the follow-up questionnaires corroborated information obtained from Questionnaires 2 and 3.

1. System Comparison. Analysis of the results indicated that the St. Regis paper bag and holder system was the most popular of the five bag systems in use, with 59.8 percent of the residents rating it higher than any of the other bag systems they used. The polyethylene can liners and the Mobil polyethylene bags and holder system followed with ratings of 41.3 and 41.2 percent, respectively; the International paper bag and holder system was next with 31.4 percent; and the Chase polyethylene bag with drawstring had the lowest rating of 28.7 percent.

2. System Improvements and Difficulties. The most marked benefit was in the effect of the bags on neighborhood appearance, both on collection day and during normal usage, with 81.2 percent of the respondents reporting improvement. Improvements in spillage problems and collection noise were noted to a lesser extent.

The difficulties which arose in placement and removal of the polyethylene liners in the cans were minor; only 14.1 percent of the respondents found difficulty installing the liners, while a slightly greater proportion, 15.3 percent, found difficulty in removing the liners from the cans when full.

The overall popularity of the bag system as an improved method of solid waste disposal was shown by 80.2 percent of the respondents who preferred the bag system to conventional cans.

3. Comments. A wide variety of comments, both appreciative and critical, were made by the residents; these are listed in Table 53.

The most frequent positive comments made were the wish to continue the bag system and noticeable improvements in neatness and efficiency of the residence and community solid waste management.

The most common criticisms of the bag system were: (1) the weakness of the bags, particularly the polyethylene 1.5 mil can liner and the 2.5 mil bags, and the consequent tearing when filled with yard waste or from animal attack; (2) difficulty in filling and closing the bags; and (3) the possibility of extra expense if the bag system were generally adopted. Failure and rupture rates for 1.5 mil bags were below the acceptable value of 65 percent, and tensile strength exceeded the derived bag materials criteria constraints. (See discussion in Section X.C.I.)

IX. BAG AND LINER MATERIALS TESTING

A. Objectives

As an alternative to field testing of all candidate systems, the results of laboratory tests which simulated bag and liner performance were used as a guide for selection of appropriate bag materials.

A complete knowledge of the behavior of a given bag or liner material requires investigation of properties under a wide range of simulated field conditions. The conduct of such exhaustive tests to obtain complete information was beyond the scope of this study. However, data was obtained on properties that had direct bearing on the economic value and field serviceability of the particular bag and liner materials. Discussions with bag manufacturers and a review of the relevant literature showed that no comparable information was available. The laboratory tests helped develop material specifications on commercially available bags used for the demonstration. Similarly, various holder and bag combinations were studied at the project engineer's laboratory to observe their storage and material handling characteristics. Free-standing bags and liners were also evaluated prior to initiating the field demonstration work.

The laboratory test objectives were:

1. To supply information on the potential field service quality of candidate bags and liners.

2. To develop supplemental information about known bag materials.

3. To measure and compare fundamental physical properties of various candidate bag and liner materials.

Table 54 presents a description of the basic dimensional properties of the various bag and liner sample specimens tested.

B. Tests

1. Tensile Stress-Strain. Tensile stress-strain properties are fundamental characteristics of each bag and liner material, and provide the most direct means of comparing different materials. Thus, knowledge of these properties is essential in any attempt to predict behavior. All materials tests were conducted in-house on a Dillon Universal Testing Machine. Standard file grips were used to minimize slippage and uneven stress distribution. The polyethylene and paper test specimens were prepared as shown in Figure 37. The specimens were carefully measured and found to have reasonably uniform thickness.

A load-elongation plotter attached to the Dillon Universal Testing Machine was used to record data for the paper specimens because of its sensitivity to the very small elongations experienced by paper. The eye loop scale measurement of strain is not accurate enough to measure the strain in paper, and the point where paper begins to tear is not discernible to the eye. The recorder indicated total cross-head movement as a function of load, and therefore is not dependant on the location of the tear (elongation). A rectangular paper specimen was used to obtain as near a uniform stress distribution as possible in order to approach the true strain. If paper specimens were prepared in the same shape as the polyethylene specimens, the recorder would not have indicated the true stress or strain. As illustrated in Figure 38, the recorder measured strain averaged over the entire length of the specimen and thus indicated the average strain rather than the maximum which occurs at the specimen center.

Polyethylene specimens were initially the same shape as paper specimens (see Figure 37), but the stress-strain values obtained from the tensile tests were not consistent due to specimens tearing at the file grips, and the insufficient range of the load-elongation recorder on the Dillon Test machine. Since the polyethylene material exhibited elastic-plastic physical properties, the specimen shape was changed to a necked-down configuration used for testing other materials with similar physical properties. The new polyethylene specimen shape (Figure 37) eliminated failure at the file grips and gave consistent stress-strain relationships. As a result of the specimen shape failures would occur at the smallest cross-sectional area, therefore standard "gauge" marks were placed on the specimen prior to testing as shown in Figure 37.

An eye loop and a metal scale were used to measure the distance between the gauge marks at increments of loading to determine polyethylene specimen elongation. At 1/4 lb load increments, the changes in gauge lengths were computed and divided by the original gauge lengths to obtain the polyethylene specimen strains. Each load was divided by the original cross-sectional area to determine the specimen stress for each strain.

Two tensile test series were conducted. In the first series the polyethylene and paper specimens were loaded until they failed. Longitudinal and transverse paper specimens were tested separately for failure loads in the second series; in contrast the polyethylene samples were loaded to an arbitrary load in the plastic range as determined by the first test series and then unloaded. Measurements were obtained of the longitudinal and transverse gauge lengths at arbitrary intervals during loading and unloading. A minimum of three specimens from each bag were used for each test. The test results are presented in the stress-strain diagrams shown by Figures 39, 40, and 41.

Two bin liner samples were tested, one from the 3 cu yd capacity and the other from the 4 cu yd. The polyethylene bin liner samples were subjected to tensile tests as discussed above. The results are presented in Figure 42. A significant difference was noted in directional strength properties for both the 3 cu yd and 4 cu yd bin liner samples tested. The breaking stress for specimens cut longitudinally with respect to the fabrication direction was greater than the breaking stress for specimens cut diagonally.

The breaking stress for specimens cut diagonally was greater than the breaking stress for specimens cut transversely with respect to the fabrication direction. The maximum stress for the longitudinal polyethylene bin liner specimens was of the same order as for the smaller household polyethylene bags (see Figures 39 and 40).

2. Cottonseed and Vegetable Oil Soak. The purpose of the cottonseed and vegetable oil soak tests was to determine the effects of prolonged exposure to cottonseed and vegetable oil on bag strength. Tensile loads were applied to specimens as described above to determine the failure load only. The specimens conformed to the specifications of Figure 37. Prior to testing, several specimens were allowed to soak in oil for 24, 48, and 72 hours at room temperature. Three specimens from each bag were soaked for each time period. Results are presented in Table 55.

3. Water, Milk, and Butter Soak. The purpose of the water, milk, and butter soak tests was to determine the effects on bag strength from saturation by water, milk, and butter. Tests to determine the failure loads were conducted in the same manner as those previously described. Three specimens (as in Figure 37) for each bag were soaked in each substance for 24 hours prior to testing. In addition, the milk specimens were allowed to soak for 24 hours at 34°F to simulate cold weather conditions.

The water tests were completed in two parts. In the first part, the specimen was tested wet after soaking for 24 hours at room temperature. In the second part, the specimen was allowed to dry at room temperature an additional 24 hours. Table 55 presents the test results.

4. Temperature Exposure. Changes in the failure loads of the bag specimens due to temperature exposure were investigated. The tests were completed as in all preceding tensile failure tests, except that the various bag specimens were exposed to either 110°F or 34°F for 24 hours prior to testing at room temperature. The results, presented in Table 55, indicate that there were little temperature effects for the paper or polyethylene specimens. These temperatures are the maximum and minimum levels expected in the City of Inglewood, California.

5. Perforation. The perforation tests were designed to investigate the effects of a punctured hole on specimen strength. Hole diameters of 3/32, 1/8, and 1/4 in. were centered at the intersection of the longitudinal and transverse axes. The specimens were similar to those in Figure 37, and were tensile loaded until failure, as previously described. Table 55 presents the results and indicates the polyethylene samples had a smaller marginal percentage strength loss with increasing perforation hole size than did paper samples.

6. Pinhole. Several small initial punctures may alter the strength characteristics of a bag significantly, and these tests were designed to investigate this possibility.

A 3/8 in. diameter circle centered at the intersection of the longitudinal and transverse axes served as the locus of a set of 10 pin holes arranged as shown in Figure 43. The tensile failure load was directly dependent on the location and arrangement of the pin holes. All specimens were loaded until failure occurred. Table 55 presents the data for the average failure loads.

7. Puncture. A bag may be punctured by the sharp corner of a box, a nail, a piece of broken glass or similar items. Puncture tests replicated and measured the resistance of bags to such failures. Puncture tests were conducted in-house on a Dillon Universal Testing Machine using a specially devised compression cage. Three series of tests using probes 1/8, 1/4, and 1/2 in. in diameter were run on specimens from each type of bag. The failure load was recorded for each test (see Table 55). For the 1/8 and 1/4 in. diameter probes, the specimens were clamped over the end of a one-inch diameter metal tube (see Figure 44) centered directly below the probe in the compression cage. The 1/2 in. probe was used with a 1-1/2 in. diameter specimen tube. The tube sizes were chosen so that the specimen would fail at the point where the probe made contact with the specimen and not along the edges of the tube. As shown in Table 55, paper bag specimens resisted punctures better than plastic bag specimens.

8. Creep. The creep tests were undertaken to determine the time rate of deformation and ultimate strain of plastic specimens under constant loading. No creep tests were conducted on paper bag specimens because paper is neither a plastic nor elastic material and therefore does not exhibit creep properties. ASTM Testing Standards (D674-56, Part 27) note that the test results for plastics are greatly influenced by material composition and atmospheric conditions of temperature and humidity. Two tests were conducted: (1) a control test at constant atmospheric conditions and (2) environmental exposure tests to duplicate climatic field conditions.

A constant 2 lb dead weight load was applied to each polyethylene specimen. The 2 lb weight was chosen to represent a bag load 110 to 140 lbs (55 inch and 71 inch circumference, respectively) which is 5 times greater than measured bag weights. The high load was chosen to represent a concentrated point load such as found from a pointed object. The dead weight was suspended from a two-inch wide metal paper string clamp which gripped the specimen evenly, thus minimizing eccentric loading. The control specimens were placed in a room where temperature could be maintained at a constant level of 74°±2 F; humidity was about constant at 70 percent, and vibration was essentially negligible. In the environmental weather exposure test, the temperature, humidity, and possible vibrations were purposely left uncontrolled to simulate field conditions. Temperatures in sunlight and darkness ranged from 60 to 100°F over 24 hours and relative humidity varied from 68 to 85 percent.

All specimens were prepared according to the dimensions shown in Figure 37. The data recorded at the end of each environmental test time interval included the date, hour, temperature, and the longitudinal and transverse gauge lengths. Initial gauge marks were set at 1/4 in. length and were measured periodically with an eye loop and a metal scale.

The total time of exposure for the test was 144 hours; incremental measurements were taken after: 1/2, 1, 2, 4, 6, 9, 24, 32, 48, 72, and 144 hours of environmental exposure. Table 56 and Figures 45 through 47 describe the results.

9. Moisture Content and Absorption. The moisture content of the paper bags was determined under laboratory conditions. Representative samples were weighed and placed in a drying oven at 100°C for 4 hours during which period the weight of the samples reached a stable condition. The moisture content of each sample was determined by subtracting the dry weight of each sample from the original weight. The percent moisture was found by dividing the moisture content by the original sample weight. Several tests were averaged, giving the following results on a wet weight basis: West Virginia - 10.3 percent; St. Regis - 9.1 percent; and Bemis - 10.8 percent.

The moisture absorption characteristics of the proper bag materials was also determined. Sample strips from each bag, approximately 18 in. by 4 in. in dimension, were weighed and then immersed in water at room temperature for 24, 48, and 72 hours. The wet samples were then weighed and the amount of water absorbed during each soak period was calculated. The quantity of water absorbed was found by subtracting the original weight of the sample material from the wet weight, and was expressed in percent of water absorbed based on the original weight. The results of the test are presented in Table 57.

10. Evaporation. Experience in Europe has indicated that a significant amount of moisture evaporates through a paper bag filled with moist waste materials. Tests were conducted to determine the percent of moisture lost from wet newsprint placed inside two paper bags and in one polyethylene bag. Sheets of newsprint were soaked in water, and then placed inside the test bags. The bags were sealed and weighed immediately, and after 24, 48, 72 and 96 hours stored at room temperature. Evaporation was calculated in terms of grams of water lost per sq in. of bag surface. The results, presented in Table 58, indicate a significant difference between the evaporation losses from paper bags and those fabricated of polyethylene material. Evaporation of moisture is an advantage if wet waste is placed within the bag, because a weight reduction would result, thus reducing the work required by the collector. However, if a paper bag is exposed to a damp environment and dry waste materials are placed in the paper bag, moisture will be absorbed into the bag increasing its weight.

11. Odor. An odor test was performed on paper and polyethylene bag samples. The test consisted of placing an ammonia solution inside the bags; sealing the bags; and checking for odor concentration using an odor panel of three previously trained observers. Odor from the paper test bags was detected from a distance of 5 feet, whereas no odor was detected from the materials placed in the polyethylene bags. More frequent animal attack would be expected if animals were able to smell the solid waste contained in a bag. Similarly, insects and vermin may be attracted more readily to paper bags.

C. Summary of Test Results

Paper bag specimens cut in the longitudinal direction were 13 to 62 percent stronger than specimens cut in the transverse direction from the same bag.

Stress-strain diagrams of the polyethylene specimens indicated definite elastic and plastic ranges. In the case of the paper specimens, the load-elongation recorder was not sensitive enough to indicate the small variations in length for the low loading ranges. When elongation was indicated, the fibers of the paper had started to tear.

Vegetable and cottonseed oil soak tests produced no diminution in the failure load or maximum loading capabilities of any of the polyethylene specimens tested. Similar tests on paper specimens showed only minor reductions in their tensile strength capabilities. The oil soak time period had no significant effect on the failure characteristics of the specimens.

Butter had a somewhat greater effect than oil on reducing the tensile strength of paper specimens, but like the oils, did not significantly alter the tensile characteristics of the polyethylene. Exposure to water and milk generally reduced the maximum strength of the paper by 80 percent. When the specimens soaked in water for 24 hours were allowed to dry for a similar period at 72°F, nearly all the tensile strength capabilities were regained. The tests also indicated that polyethylene was unaffected by either milk or water.

Temperature exposure prior to tensile testing at room temperature did not significantly alter either polyethylene or paper bag failure loads.

The data from the perforation and puncture tests yielded expected results. As the perforation hole diameter increased, the failure load decreased. As the puncture hole diameter increased, the failure load decreased. As the puncture probe diameter increased, the load required for failure also increased. The polyethylene puncture resistance for 1/2-in. probes was greater than its tensile failure load. The paper failure load decreased significantly with larger perforations, whereas the polyethylene failure loads remained unchanged or decreased slightly. The holes had a greater effect on paper strength as a percentage of tensile strength, than on polyethylene.

The creep tests indicated that exposure to sun and heat influenced the maximum strain of the polyethylene specimens. Humidity did not appear to be a major factor in the creep test results since the range of humidity the environmental specimens experienced did not vary greatly from the control room humidity. All of the test specimens exposed to high and low temperatures indicated a higher rate of initial strain than that of the control test specimens, but after the first 8 hours of exposure time the environmental and control specimen rates of strain were identical. Creep rates of the environmental specimens increased during mid-day when the temperature was greatest and the sun brightest.

X. FORMULATION OF BAG EVALUATION CRITERIA

A. Approach

The objectives of developing bag system evaluation criteria were threefold: (1) to establish minimum standards for proposed bag material specifications; (2) to provide a rationale for comparing bag system performance; and (3) to formulate bag system selection criteria.

Two approaches were developed for evaluating bag systems; one based on materials properties and field performance, and the second derived from consumers' preferences and field performance. The first method consisted of relating the properties of bag materials to the bag failure rates in the field. The second method was derived from questionnaire responses from the householders using the bags. The fibrous composition of the paper bags results in different materials properties than the plastic nature of the polyethylene bag material. Consequently, they are discussed separately in the materials property evaluation.

B. Materials Properties

Results from the laboratory tests were used to derive basic properties of the bag materials. These derived properties were used to investigate corroboration between laboratory test results and field performance.

Table 59 lists the dimensional characteristics, and Table 60 the physical properties of the demonstration bags which provide the most significant indices of field performance. The definitions of technical terms which are not immediately obvious are described in Appendix A, Glossary. Both paper bags were of two-ply wet strength construction, and the combined properties of each ply are listed. Ultimate tensile strength data is presented for paper bags in both the dry and wet states, since the wet paper exhibited substantially lower strengths than dry paper. Solid wastes commonly include liquids and often contain moist materials (see Plate 2E), consequently realistic evaluations require consideration of the wet-strength properties of the paper bag. The polyethylene bags were unaffected by water or oils, and consequently only the results of dry tests are included in Table 60.

1. Polyethylene. The energy absorption potential of polyethylene is an important measure of the ability of the material to resist puncture and propagation of tears. Table 63 lists values of strain energy, u^*, for specified bag thicknesses; these values range between 11.8 in.-lb/in.^{2} and 21.9 in.-lb/in.^{2} for polyethylene. Strain energy, u, is equal to the area under the stress-strain curve which, when multiplied by the bag thickness, gives u^*. A study of this table indicates that all polyethylene specimens had ultimate stresses of approximately equal magnitude with no specimen less than 2,000 psi; also a wide range of strain values ϵ_u, and consequently u, are obtainable with the indicated 20 percent variation in stress.

Thus, for two bags of equal polyethylene film thickness, the one with the higher value of u should perform best; alternatively, irrespective of bag thickness, a bag with a higher value of u* should give the better performance.

The existence of a definite relationship between u* and field performance is substantiated by bag failure rates reported during the field demonstration. Bag ruptures and failures were counted in areas A, B, and C during the first bag distribution, and in areas B and C during the second distribution. Figure 48 shows a plot of bag failures and ruptures versus u*. Skin rupture is defined as punctures and tears, and does not necessarily imply destruction of waste holding capability; bag failure is defined as a condition where the contents of the bags are spilled. Thus the ordinate in Figure 48 is the total percentage of reports of skin ruptures and bag failures combined. The two data points are shown with an assumed linear relationship connecting them, which may be expressed mathematically by

$$F = -2.58\, u^* + 100 \qquad (1)$$

where F = percent failure, and u^* is in units of in.-lb/in.^{2}.

A third point is provided by assuming that 100 percent failure rate would occur at zero value of u*; this defines the curve as linear.

Each of the two data points describes two different bags with nearly identical values of u*, i.e., point 1 combines data for two bags listed in Table 59 (the 30 gal Mobil Keepaway, and the 33 gal Friedman Narrow bag), while point 2 combines data for two liners listed in Table 59 (the Friedman Wide and Wagner liners). The data for point 1 is based on data for bags of slightly different capacity used on holders, while data for point 2 is based on data for bags used as liners. The type of bag support system and bag/liner capacity could also appreciably influence bag failure and rupture rates. For example, there is a factor of two difference in the sizes of bags in the data points with point 1 being based on 30 and 33 gal sizes and point 2 on 60 gal sizes. It seems logical to anticipate greater failure rates in the larger, more heavily loaded bags. It is quite possible, therefore, in view of the fact that Figure 48 indicates the opposite results, that bag size, support, and closure conditions offset each other. The results indicate, however, that the total available data for the polyethylene bag supports the hypothesis that u* is a significant measure of structural performance.

It should also be noted at this point that the bag materials test data discussed previously includes the results of puncture tests. These results are not conclusive, but do tend to support the hypothesis that u* is an appropriate measure of puncture resistance; e.g., for two bags of different thickness, the Friedman and Wagner liners, identical values of u* were obtained, but the failure loads under comparable conditions were different (see Table 55). The differences in failure loads are, in all cases, less than the 17 percent difference in thicknesses. The puncture tests, however, were conducted under ideal conditions; e.g., in an equal biaxial stress field, and thus may not represent accurate simulation of actual field conditions.

Both logic and field test experience indicated that it is impractical and unnecessary to seek a bag which is 100 percent resistant to all rupture. Thus it is necessary to define those limiting values of u^* which give an acceptable rate of bag failure in the field. A study of Figure 49 and Equation (1) indicate that failures may be substantially reduced only by increasing thickness of polyethylene bags above approximately 5 mil. On the other hand, bags for which $u^* = 10.0$ in.-lb/in.^{2} may not be appreciably inferior to those now in use; i.e., total percent failure may be 75 percent rather than 65 percent.

Since the responses to the demonstration questionnaires indicated that the rate of failures of the demonstration bags were satisfactory to the householder and collector, it may be assumed that a minimum value of $u^* = 10.0$ in.-lb/in.^{2} would give an acceptable failure rate.

The tensile behavior of the polyethylene bag specimens, shown in Figures 39 and 40, makes it desirable to specify a constraint on the minimum allowable working stress in addition to a minimum value of u^*. This will provide a factor of safety against thick polyethylene specimens which have acceptable values of u^*, but low ultimate stress σ_u, and a relatively large strain ϵ_u. The test specimens corresponding to a 65 percent failure rate all had values of σ_u equal to or greater than 2,000 psi; therefore this value was taken as an acceptable minimum.

2. Paper. Two different paper bags, the St. Regis and the International, were tested, both in the laboratory and the field. Although they were both two-ply bags, the International bag was constructed with both plys glued together so that they functioned under load as a single layer. The reported failure rates for both types of bags were not dramatically different (47 percent for the International single-layer bag, 39 percent for the St. Regis double-layer bag). It seems logical to expect greater failure in the larger International bag which could be more heavily loaded, and the reported failure rates seem consistent with this view. Although laboratory and field test data were available for only two paper bags, the performances noted above once again appear to be related to strain-energy; i.e., the value of u^* for the dry two-layer St. Regis bag is 2.43 in.-lb/in.^{2}, and for the dry single-layer International bag is 2.11 in.-lb/in.^{2}. The relative equality of failure rates for the two types of bags may be a consequence of the similarities in energy absorption capacities.

The test data for the St. Regis two-ply bag indicates that strain-energy for the wet paper is 58 percent of the dry paper value. Thus it appears (Table 55) that wet-strength paper bag values of u will generally be about 50 percent of the dry-strength values.

Since the householders found the rate of failure of the two paper bags acceptable, it may be assumed that bags satisfying the minimum values of u^* (dry) = 2.0 in.-lb/in.^{2} and u^* (wet) = 0.5 u^* (dry) would give an acceptable failure rate during service.

The lack of ductility, evident in the tensile behavior of the paper bag specimens shown in Figure 42, makes it unnecessary to specify a constraint on the minimum allowable ultimate stress of the paper material. Values of u* will be more greatly influenced by σ_u than by ϵ_u, and a constraint on u* therefore implies a constraint on σ_u.

C. Criteria for Bag Selection

The basic parameters which dictate the acceptability of a bag for use as a container for solid waste are (1) the cost and (2) the strength of a bag with respect to its failure rate under field conditions. The preceding section has shown that u* and σ_u are practical measures of resistance to failure during use, and as long as acceptable minimum requirements for these two quantities are met or exceeded, the determining factor for bag selection will be the cost. The additional expense of the bag systems was disliked by many respondents to Questionnaires 2, 3, and 5 (Tables 40 and 46). Thus, cost is a valid method for selecting a bag from among several alternatives which satisfy the materials constraints. The following two sections present specific criteria for selection of polyethylene and paper bags, respectively, from this viewpoint. The fundamental differences in material characteristics make it necessary to treat each category separately.

Although failure rate and cost are undeniably basic parameters affecting bag performance, and consequently bag selection, it is recognized that many other factors may influence overall performance, e.g., bag dimensions, ease of closure, type of holder, etc. Also such aesthetic factors as improvement of neighborhood appearance may be considered. These other performance factors and householder preferences are included in a third section which proposes a format for total evaluation of solid waste bags.

1. Proposed Criterion for Selection of Polyethylene Bags. Considering the factors discussed above, the proposed criterion for evaluation or selection of plastic bags may be simply stated as follows:

minimize: c^* (2)

subject to: $u^* \geq 10.0 \text{ in.-lb/in.}^2$ (3)

$\sigma_u \geq 2{,}000 \text{ psi}$ (4)

These constraints will limit the plastic bag failure and rupture rates to less than 65 percent under the field use conditions encountered in Inglewood. In order to account for different bag sizes, relative costs are compared; therefore c*, the cost per unit of bag capacity is used. This quantity is shown in Table 60 for the demonstration bags.

Inequalities (2 to 4) imply that various "standardized" bag sizes will be compared, and that only certain discrete combinations of diameter and length are acceptable for standard holders.

Thus, for equal values of c^*, the preferable material is the one with the highest value of u^*, provided σ_u is no less than 2,000 psi. Alternatively, for equal values of u^*, the bag with the lower relative cost is preferable.

Constraint (3) also defines acceptable values of u for different bag thickness. The relationship is shown in Figure 49.

2. Proposed Criterion for Selection of Paper Bags. In order to express failure rate for paper bags as a function of energy absorption capacity, both the dry and wet state minima must be specified.

A preliminary criterion for selection of paper bags should be based on the fact that both bags which were tested in the laboratory have proven satisfactory with respect to rate of failure in field performance. Thus, a selection criterion can be simply stated as:

minimize: c^* (5)

subject to: $u^*_{\text{dry}} \geq 2.0$ in.-lb/in.^{2} (6)

$u^*_{\text{wet}} \geq 0.5\, u^*_{\text{dry}}$ (7)

where u^* represents the summation of values for each ply of a multi-ply bag. The criteria given by inequalities (6) and (7) assumes no inherent structural advantage of multi-layer bags over single-layer bags.

3. Algorithm Formulation for Total Evaluation of Bag Suitability. The following factors have all been found significant, to different degrees, when determining the relative suitabilities of different solid waste demonstration bag systems.

(1) Frequency of bag failure

(2) Ease of closure of filled bag

(3) Ease of mounting bag or liner

(4) Ease of filling bag

(5) Odor control

(6) Frequency of spillage

(7) Frequency and extent of animal damage.

All of these factors apply to both bags with holders and to liners.

Other factors affecting performance exist and could be included in an expanded format as they become well-defined. Also, several factors related only to bags or liners were not included because they are not relevant for comparisons between bags and liners.

In order to obtain a total preference rating of a bag system, the above factors may be considered in an algorithm evaluation format as follows:

$$\text{total bag rating (TBR)} = \sum_{i=1}^{7} a_i b_i \qquad (8)$$

where a_i is the rating of a particular bag with respect to each of the seven factors, and b_i is a weighting coefficient for the relative importance of each factor in overall performance.

Bag ratings, a_i, were obtained from algorithm analyses of the residents' responses to Questionnaires 2, 3, and 4, the highest bag rating being arbitrarily assigned the value of 10. The list of the ratings is presented in Table 61.

The weighting coefficients, b_i, were obtained from the ratings of relative importance given to the factors 1 through 7 by the respondents to Questionnaire 5; a summary of the number of responses is given in Table 62, and the corresponding percentages of the total responses in Table 63. From these percentage ratings the weighting coefficients, b_i, were calculated by arbitrarily assigning values of zero, one, two, and three to the "none", "very little", "moderate", and "great" percentage ratings, respectively, and then summing for each factor. The algorithm weighting coefficient for each factor was then expressed as the quotient of this summation over the total of all the summations. Thus for each bag system:

$$\sum_{i=1}^{7} b_i = 1.0 \qquad (9)$$

These weighting coefficients are presented in Table 64. A study of these weighting coefficients indicates the relative importance attached by the residents to each factor listed; the higher the weighting factor, the more important is the particular factor to the householder. "Odor control" is suprisingly the most important single factor listed; the remaining factors are rated as anticipated.

The weighted bag ratings, $a_i b_i$, were obtained and are given in Table 65, together with the total bag ratings for each bag system.

4. Bag System Comparisons. A study of the algorithm results for total bag

ratings given in Table 65 provides a relative comparison between the demonstration bag systems.

Both Mobil bags were 2.5 mil bags and, for purposes of this anulysis, were considered as one type of bag since there was no indication of their having any differences in performance; although the Mobil Keepaway has a smaller capacity, it did not influence the bag rating.

Table 65 shows that the Mobil system was given the highest total bag rating of 10.0 by the residents of the Briarwood condominium, thus indicating it to be the best liked system; the Mobil Keepaway bag, however, previously received a relatively low total bag rating from the respondents to Questionnaires 2 and 3. The difference in ratings of these essentially similar bags is due to the different holders used. Complaints were received from respondents to Questionnaires 2 and 3 about the poor operation of the original holder lid which subsequently biased the residents' questionnaire response. The holder design was corrected before distribution to the Briarwood condominium residents and the resulting higher rating given by respondents to Questionnaire 4 provides the more reliable result for the Mobil polyethylene bags and modified holder. This incident illustrates the importance of the total bag system, including the holder, in obtaining consumer acceptance of bag systems.

Average values of 9.182 for the St. Regis paper bag, and 8.652 for the International paper bag may be used for comparison since the weighted ratings from each of the 3 questionnaires do not vary greatly from one another.

The total bag ratings for the two can liners give a similar result; the average of 9.786 may be used for comparison.

The Mobil system of a 2.5 mil polyethylene bag on a holder, and the polyethylene can liners rate highest in the comparison, followed by the St. Regis and the International paper bags. The lowest rated bag is the free-standing St. Regis paper bag, but due to the relatively small quantity distributed and total rating based on responses to Questionnaire 2 only, the absolute rating value of this last result may not be directly comparable. The relative ranking, however, is probably accurate.

The sensitivity of the algorithm ratings derived from the responses to the 3 demonstration questionnaires indicate that the format for total evaluation provides an acceptable rationale for determining the overall suitability of bag systems for field use.

XI. ECONOMIC ANALYSIS

A. System Simulations For Cost Analysis

The impact of disposable solid waste bags on collection efficiency was investigated by the use of a mathematical model developed by the project engineers.[2] This model defines the time required for waste collection, and when actual cost data for labor and equipment are provided, it can be used to estimate collection costs for a particular service. An IBM 360 computer was used for processing the calculations. Figures 50 through 60 were developed from the computer output to indicate the effects of certain variables on the efficiency of the waste collection service, and to specifically determine the influence of bags.

Variables included for the mathematical model simulations were: (1) truck capacity; (2) quantity of waste at each service stop; (3) time for the collection of a service stop; (4) travel to the next service stop; (5) the density of waste materials when compacted in the collection vehicle; (6) the haul time; and (7) the non-productive time of the crew. The non-productive time includes time spent by the crew for relief, dispatch, lunch, and for miscellaneous travel. The mathematical model simulates the operations of a single truck and crew during one day's work activities. Any of the above-mentioned parameters may be varied independently to determine its effect on waste collection efficiency.

The basic relationship of the model formulation is as follows:

$$X = \frac{Vtd}{Q} + B + K + D$$

where X = the total time to complete a day's work (min);
V = vehicle volumetric capacity (cu yd);
t = mean time per collection stop plus travel time to the next stop (min/stop);
d = mean density of waste in the vehicle (lb/cu yd);
Q = mean quantity of waste per collection stop (lb);
B = the one-way average driving time between the route and the disposal site (min);
K = the total non-productive time (min). Includes dispatch, lunch, relief, yard to route time, and disposal site to yard time; and
D = the mean disposal time (min/load).

A brief description of the model is given in Appendix I which includes assumptions, data inputs, and model logic.

On each of the figures the abscissa represents the volumetric capacity of the waste collection vehicle. The estimated cost data for the collection equipment is presented in Table 67. The (1969-70) labor cost for Inglewood was $4.80 per hour, including fringe benefits. For the mathematical model simulation, the mean density of the waste in the collection vehicle was assumed to be 550 lb per cu yd. The mean disposal time (D) was assumed to be constant at 10 minutes per load. The assumed values for the remaining variables in the above formula are indicated on each of the figures. The abbreviation (CS) signifies the number of men in the crew including the driver. Figures 50 through 60 relate to curbside collection of residential waste and represent a standard 8 hour work day with 30 minutes maximum overtime. Calculations were made for crew sizes of one, two, and three men, respectively. Times for two and three man crews were derived from MTM analyses and the One-Man-Report as described in Appendix I.

The use of disposable bags for waste containers primarily affects only the value of the time required for collection of the service stop. This time quantity plus the travel time to the next collection stop is designated as t. Values for t, based on the results of the two-year study program, were used in the mathematical model to estimate the effect of disposable containers on the number of services collected per crew; the cost per ton for waste collection; the man-minutes per ton; and the average cost per service. Table 66, indicated the values of time, t, in minutes per stop used in the mathematical model simulations.

Irregularities (nonlinearities) in the total cost, collection time, and number of services curves are mainly due to the collection of partial loads and the occurrence of overtime. The return to collect a small partial load, particularly where the haul time, B, is large may be quite expensive on a unit cost basis. The model restricted partial loads to those greater than one-eighth of a full load in an attempt to reduce their effect on costs. Waste collected on overtime costs more per unit of waste than that collected on regular-time. However, once a truck and crew are on the route collecting waste, if the truck has remaining capacity to collect an additional quantity, it is more economical to let that crew continue to collect overtime than to schedule an additional truck and crew for a full day's operations, unless the additional waste is sufficient to keep the crew active for most of the day.

Figures 50 through 52 show collection times for bags and cans in man-minutes per ton as a function of truck volume in cu yd. For these three figures, the values for items K, B, and Q were assumed as 100, 50, and 60, respectively. Referring to Figures 50 through 52, it is seen that the use of disposable bags reduces collection time. For example, assuming a truck volume of 25 cu yd, the collection time for a three-man crew is reduced from 123 to 99 man-minutes per ton, or a reduction of nearly 20 percent over the value without using disposable bags. For the one- and two-man crews, using a 25 cu yd truck, collection times are reduced from 53 to 41 and 98 to 76 man-minutes per ton, respectively, or about 23 percent. Figures 50 and 51 indicate that in the case of the one- and two-man crew sizes, as the truck volume increases the savings in using disposable bags decreases. However, in Figure 52, with the three-man crew, the savings increase until a 32 cu yd truck volume is reached, and then remains constant up to 40 cu yd. These relationships hold for the values of K, B, and Q indicated. The K, B, and Q values were chosen in this instance as being representative of verified field conditions encountered in the City of Inglewood.

Using the same values for K, B, and Q, and for t, the effect of the reductions in collection time on average cost per service can be calculated. Figures 53 and 54 illustrate this effect. From Figure 53 it can be seen for a one-man crew and a 25 cu yd truck, the savings due to the use of disposable containers were estimated to be approximately 6 cents per service. This savings would occur each time a stop is serviced (once per week at Inglewood).

This savings does not include the cost of the disposable bags, but represents only the savings in cost associated with the reduced collection time. Figure 54 indicates that for the 25 cu yd truck and a two-man crew, a savings in collection cost of about 9 cents per service would be realized. In the case of the three-man crew, and a 25 cu yd truck, a savings of about 7 cents per service is indicated. Additional savings from the three-man crew are realized when trucks with a capacity of 30 cu yd and larger are used. For example, from Figure 55, if a 32 cu yd truck were used for the three-man crew, the savings in cost could be 12 cents per service.

Calculations were made to determine the effect of disposable bag use on the number of services which a collection crew could complete during a normal work day. For the specified K, B, and Q values, Figure 56 was prepared showing the number of services collected by the one-man crew assuming the use of conventional containers and disposable bags. Figure 56 indicates that additional services may be collected by the crew using the disposable bags. For the 25 cu yd truck, as an example, the number of services collected per crew can be increased from 325 to 411. The increase in the number of services per truck indicates that the area could be collected with fewer trucks and crews if bags were utilized.

Figure 56 also indicates that a 20 cu yd truck and one-man crew using disposable bags can collect as many services per day as a 40 cu yd truck using conventional hard containers. This indicates that for a collection system with a given number of 40 cu yd trucks handling conventional containers, and with the indicated K, B, and Q values, the conversion of the entire collection area to disposable bags would permit the replacement of the 40 cu yd trucks with an equal number of 20 cu yd trucks. The impact of this change on the cost per ton for waste collection with a one-man crew is indicated in Figure 57. The cost per ton using conventional containers and 40 cu yd trucks is approximately $7.10 per ton. The substitution of 20 cu yd trucks for the 40 cu yd trucks would result in a reduction in the cost to approximately $6.70 per ton. This savings is due to the decreased capital and operating cost per service. Figure 53 indicated that the substitution of 20 cu yd trucks and disposable bags for a collection operation using 40 cu yd and conventional containers can achieve a reduction in cost from 23 cents to 20 cents per service. Figure 50 presents collection time as a function of truck volume for the one-man crew; the substitution of a 20 cu yd truck for a 40 cu yd truck is expected to result in an increase in collection time from 39 to 44 man-minutes per ton. Thus, there is reduced collection labor efficiency. However, this may be offset by the decreased cost of the equipment operation and maintenance.

The curves shown in Figure 53 to 55 illustrate the aforementioned cost evaluations, as well as the practicability of the mathematical model for simulating a known system. Of course, it is necessary to obtain appropriate field values for a given system and to verify the applicability of the simulation model. The model can then be employed to determine savings which may accrue with system improvements such as the use of disposable bags.

The variation of cost per ton, the number of services collected per crew, and the man-minutes per ton with changes in K, B, and Q has been simulated. Figures 58 to 60 were prepared assuming the City of Inglewood's one-man crew operating with a conventional container route with one curbside collection per week. Figure 58 indicates the impact of changing disposal site travel time values from 10 to 30 to 50 minutes on the solid waste cost per service. Because B represents the one-way haul time (proportional to haul distance), this figure simulates the effect of changing the location of the disposal site. Figure 59 indicates the effect on Inglewood's cost per service from changes in the total non-productive work time from 50 to 75 to 100 minutes. It is seen that with a one-man crew system, the non-productive work time parameter, K, has limited impact on the cost per service. The effect of changing the average quantity of waste per service stop from 50 to 60 to 70 lb is indicated in Figure 60. Here again, the sensitivity of the cost per service to changing the average quantity of the waste per stop is small.

B. Container System Operating Costs

Cost comparisons of can, bag, and container liner systems were completed for two alternative methods of bag distribution: one where the householder purchases the bags at private retail outlets; and the second where the solid waste system management provides distribution of bags and liners directly to the householders. The costs were calculated for seven alternative container configurations: (1) metal cans; (2) light duty plastic cans; (3) heavy duty plastic cans; (4) polyethylene liners in metal cans; (5) polyethylene liners on holders; (6) paper bags on holders; and (7) polyethylene bags on holders. All containers in the analysis are normalized at 32 gal in capacity. Dimensional properties of the Mobil 1.5 mil Luxri polyethylene can liner, Mobil Keepaway 2.5 mil polyethylene bag, and St. Regis paper bag used in the cost analysis are given in Tables 54 and 60. Collection costs for curb collection, used in this analysis, were computed using the mathematical simulation model.

A unit cost breakdown for each container system component and related collection costs are given in Table 68. Cost analyses were made for City (public) distribution with bags purchased at wholesale prices and public buying of bags and holders at retail outlets; the data is summarized for the 25 and 35 cu yd capacity collection trucks used in Inglewood. The costs for City distribution are given in Table 69 and retail purchase costs in Table 70. The cost of can containers has not been included in the City costs because they are purchased by residents. The savings in collection system costs achieved with bags over cans is not great enough to offset the additional cost of the bags and holders. The least expensive system to residents is the metal can as presently used; at $19.49 per residence per year retail (Table 70), cans are $1.05 per residence per year less than the $20.54 polyethylene liner-in-can system. Paper bags are the most expensive system costing from $26.82 to $32.04 per residence per year for retail and City distribution. The difference in costs between 25 and 35 cu yd capacity collection trucks ranged from $0.75 to $0.86 per residence per year depending on the number of containers and system collected. Collection vehicle cost differentials reflect differences in vehicle costs and capacity.

C. Householders' Economic Benefits

An analysis of intangible householder benefits associated with the use of bags and liners and their effects on collection system costs is given in Table 71. A potential benefit value of $6.76 was derived from estimated costs of time and materials for cleaning cans which would not be accrued with bags and liners. These indirect charge benefits do not accrue to the City, however, and therefore can only be assigned to residents purchasing cans at retail outlets. When these intangible benefits are considered, the polyethylene liners and paper bags are less than or equal to, respectively, in cost to the common metal can system. The householder's response to the demonstration programs' second through fifth questionnaires were highly favorable to the bag systems, therefore, the benefits, although intangible in terms of householder's labor, may be treated as an incentive for using bag systems.

D. Collection System Economics

The costs discussed previously indicated that polyethylene liners in cans would be the least expensive solid waste container system if public distribution costs are excluded. There are, however, definite advantages to a City liner distribution system because the City could maintain standard bag characteristics and cost control through large quantity contract purchasing. Distribution could be made from public buildings such as the City Hall, the City Yard, fire stations, etc., and householders would be billed for liner cost plus distribution cost. The preferred bag distribution method requires a policy decision by the City. The cost of distribution to keep total collection system costs equal to or less than present can costs should be less than the difference between can and net liner system costs. This difference can be utilized as a distribution system decision constraint. For example, the average retail cost difference to Inglewood householders between the can and liner-in-can system is $2.44 per household per year; this was derived by averaging the products of the number of each size truck times the respective can-liner differences. The differences in total collection costs, $2.68 for the eighteen 35-cu yd trucks and $1.05 for the three 25-cu yd trucks (Table 70). The cost of distributing bags and liners during the demonstration study was $4.34 per household per year. The demonstration test distribution costs, however, were high because the collector's personnel explained the use of the systems to householders during bag and liner distribution. Thus, it appears reasonable to constrain distribution costs to less than $2.44 per year per household in Inglewood, so that polyethylene liners in cans would be economically competitive.

Assuming that liners would be distributed to each household quarterly, the approximately 29,660 household and apartment stops would be served every 13 weeks, for about 457 stops each day, or 57 stops each hour on the average. For example, if the equivalent of two full-time employees at $12,000 per year in wages and 125 percent overhead, general and administrative costs could handle distribution of the liners, the cost would be $27,000 per year or $0.75 per year per household (36,000 households).

This estimated distribution cost falls within the constraint and would result in a total net yearly cost to householders of $18.58 for the City collection system per household serviced per year. This cost is competitive with the total household cost of $19.49 per year for the present system when the cost of cans is included.

E. Incentives for Use of Bag Systems

Other cities have reported that distribution of bags to residents was a major deterrent to their use. Experience has shown, as have the results of the questionnaire survey previously discussed, that the public is reluctant to accept a change in service if additional cost is involved. Once the public has used bags, however, they indicate a preference for bag systems if little or no increase in cost is involved. The results of the bag use follow-up survey in Inglewood indicated that most householders generally did not continue to use bags after their free supply was depleted. Those that continued using bags bought the least expensive bag, the 1.5 mil polyethylene bag and liner.

The major difficulty to surmount in developing an incentive program to promote the use of bags for solid waste collection is cost. Given cost as a constraint, an incentive program for bag use could be developed along one or more of the following lines:

1. The residents have already invested in cans. This investment can be preserved by using polyethylene can liners which are also the least expensive of the bags and liner systems. Neither the City nor the residents would therefore incur additional costs for holders during the introduction of a City-wide bag system.

2. The City could purchase and distribute liners to residents. The collection cost savings could be used in either of the following two ways:

   a. Collection fees remain the same but liner purchase and distribution cost is offset by the saving in collection cost attributable to using liners.

   b. Collection fees are reduced by the amount of collection cost savings attributable to liner use. Liner and distribution costs are billed separately; residents pay the full cost of liners plus distribution.

The best approach would be alternative 2.b, which separates the two costs so that collection savings can be emphasized. Residents can also be given the alternative to purchase liners or bags at retail and still have their collection fees reduced. Other methods of utilizing collection cost savings such as building a transfer station and changing collection vehicle capacities are not economically feasible at present (1970) for Inglewood.

Incentives for using liners (or bags) should emphasize: collection cost savings; reductions in noise, litter, odors, spilled containers, and fly larvae production; a general improvement in neighborhood appearance resulting from the absence of empty cans at the curb following collection; and the elimination of the task of carrying empty cans from the curb to the yard.

Incentives for residents using their cans as holders are the savings in time and materials expense for cleaning cans, and longer can life when a "protective" liner is used. Residents would be requested to clean their cans thoroughly prior to using them as holders to realize the full benefits of the system.

In order to improve acceptance, the introduction of a bag or liner system would have to include an educational program to stress the incentives. The residents should be given the alternative of purchasing bags, liners or holders on their own while stressing that the City could supply them at lower cost.

A City ordinance specifying standardized bags and liners for use would be helpful if instituted concurrent with their introduction. Residents would feel more inclined to cooperate if they knew their neighbors also had to comply.

Other collection system configurations can be formulated to take advantage of the curb collection cost savings projected for bags and liners in Inglewood. Detailed mathematical model simulations of various possible collection system configurations and their related costs would be necessary to finalize a system design. Based on the requirements of the most suitable system, a recommended plan of action for its implementation could then be developed.

TABLE 1

CLIMATOLOGICAL DATA[a]

Month	Temperature F Avg Max	Avg Min	Avg	Highest/Lowest	Precipitation (in.) Total	Greatest Day	Field Test Periods
1968							
June	71.5	60.9	66.2	78/58	T[b]	T	
July	73.2	63.4	68.3	80/59	0.04	0.04	
Aug.	74.1	62.9	68.5	90/59	T	T	
Sept.	74.5	62.6	68.6	95/57	0.00	0.00	x
Oct.	72.0	58.6	65.3	94/55	0.32	0.13	x
Nov.	69.7	53.7	61.7	83/43	0.24	0.15	
Dec.	63.0	45.5	54.3	79/32	1.42	0.80	
1969							
Jan.	62.6	51.2	56.9	82/39	9.60	2.63	
Feb.	59.6	48.2	53.9	73/42	3.76	0.89	
March	63.4	49.4	56.4	80/40	0.42	0.23	
April	66.0	54.6	60.3	81/47	0.38	0.24	
May	67.8	58.4	63.1	72/50	T	T	x
June	69.7	61.2	65.5	78/58	T	T	x
July	73.7	64.5	69.1	79/60	0.15	0.15	x
Aug.	76.7	65.3	71.0	86/60	0.00	0.00	
Sept.	71.9	62.3	67.1	82/59	0.01	0.01	
Oct.	73.9	58.3	66.1	88/52	0.00	0.00	
Nov.	74.1	54.4	64.3	84/44	1.37	1.26	
Dec.	66.4	51.1	58.8	82/39	0.01	0.01	
1970							
Jan.	63.6	50.2	56.9	73/37	1.44	0.67	x
Feb.	69.5	51.8	60.7	83/46	1.39	0.66	x
March	66.3	52.4	59.4	74/47	1.29	0.89	x
April	67.4	51.2	59.3	82/45	T	T	x
May	69.9	56.7	63.3	94/51	T	T	x
June	77.9	62.0	70.0	96/56	0.04	0.04	x
July	85.3	65.3	75.3	96/60	0.00	0.00	x

[a] Los Angeles International Airport.
[b] T = trace.
Source: U.S. Department of Commerce.

TABLE 2

OPERATING STATISTICS
CITY OF INGLEWOOD COLLECTION OPERATIONS

Year	Man-Hours	Tons [a]	Average Load Size (Tons)	Man-Hours Per Ton [b]
1960	52,170	24,220	4.14	2.19
1961	49,155	28,746	4.81	1.72
1962	49,067	30,869	4.97	1.63
1963	47,842	32,388	5.65	1.48
1964	37,967	32,500	7.27	1.17
1965	39,661	34,699	7.77	1.15
1966	40,846	35,208	7.75	1.16
1967	39,742	36,502	8.24	1.09
1968	36,949	35,349	8.11	1.04
1969	36,533	37,529	8.66	0.97
1970[c]	18,964	18,154	8.13	1.04

[a] All loads are weighed at the disposal site.

[b] The performance rate was calculated based on paid direct collection labor hours including supervisory personnel, and tonnage from scale receipts. High performance rates of about 1.0 man-hours per ton have been of local and national interest.

[c] January-June, inclusive.

TABLE 3

STUDY AREA DESCRIPTION

Study Area and Route	Total Route Length (mi)	Units Single Family	 Multiple	 Commercial	Total Stops	Total Residential Units
A1	4.2	267	1	0	268	271
A2	4.0	233	13	2	248	294
B3	5.7	314	0	0	314	314
B4	5.4	326	0	0	326	326
C5	5.0	82	86	0	168	656
C6	6.8	106	80	0	186	550
Total	31.1	1,328	180	2	1,510	2,411

TABLE 4

INITIAL FIELD SURVEY, CONTAINERS[a]

Study Area	A				B				C			
Route	1		2		3		4		5		6	
Week	Mean[b]	S.D.[c]	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	2.77	1.19	2.74	2.87	N.D.[d]	N.D.	3.05	1.56	N.D.	N.D.	4.14	1.88
2	2.75	1.13	2.75	1.61	2.74	1.19	2.62	0.98	4.70	2.97	3.17	1.66
3	2.68	1.23	2.72	1.55	2.51	1.01	2.53	1.12	4.33	2.79	3.48	2,48
4	2.74	1.25	2.82	1.36	2.51	1.00	2.62	1.05	3.79	2.65	3.35	2.12
Composite	2.74	1.20	2.75	1.57	2.59	1.08	2.69	1.19	4.31	2.85	3.49	2.38
Total Stops[e]	1,031		921		897		1,031		405		676	

[a] Cans only. Study was made prior to distributing bags.

[b] Number of cans per stop.

[c] Standard deviation of the number of cans per stop.

[d] Not determined.

[e] Total collection stops made during study period.

TABLE 5

INITIAL FIELD SURVEY, ITEMS[a]

Study Area	A				B				C			
Route	1		2		3		4		5		6	
Week	Mean[b]	S.D.[c]	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	3.98	2.46	3.64	2.50	N.D.[d]	N.D.	3.42	1.80	N.D.	N.D.	6.49	4.62
2	3.98	2.60	4.07	2.69	3.66	2.07	3.23	1.68	6.22	4.80	5.83	4.50
3	3.86	2.52	3.76	2.45	3.77	2.30	3.72	2.43	7.04	5.16	5.66	4.55
4	3.93	2.44	4.26	2.49	3.82	2.33	3.73	2.19	6.81	5.48	5.58	4.19
Composite	3.94	2.51	3.94	2.54	3.75	2.23	3.53	2.07	6.66	5.16	5.85	4.47
Total Stops[e]	1,031		921		897		1,031		405		676	

[a] Total items including cans. Study was made prior to distributing bags.

[b] Number of items per stop.

[c] Standard deviation of the number of items per stop.

[d] Not determined.

[e] Total collection stops made during study period.

TABLE 6

INITIAL FIELD SURVEY, COLLECTION TIME (MINUTES)

Study Area	A				B				C			
Route	1		2		3		4		5		6	
Week	Mean[a]	S.D.[b]	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.53	0.32	0.53	0.37	0.54	0.32	0.52	0.29	0.82	0.66	0.90	0.64
2	N.D.[c]	N.D.	0.51	0.40	0.54	0.34	0.55	0.33	0.90	0.59	0.79	0.61
3	0.60	0.38	0.71	0.49	0.65	0.35	0.57	0.33	0.94	0.70	0.86	0.63
Composite	0.57	0.37	0.62	0.51	0.58	0.34	0.55	0.33	0.88	0.66	0.87	0.65
Total Stops[d]	516		692		897		849		405		535	

[a] Minutes per stop, includes only actual time at a stop; does not include travel time. Study was made prior to distributing bags.

[b] Standard deviation of the collection time per stop.

[c] Not determined.

[d] Total collection stops made during the initial field study period prior to distributing bags.

TABLE 7

INITIAL FIELD SURVEY, TRAVEL TIME BETWEEN STOPS (MINUTES)

Study Area	A				B				C			
Route	1		2		3		4		5		6	
Week	Mean[a]	S.D.[b]	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	0.12	0.16	0.12	0.17	N.D.[c]	N.D.	0.10	0.12	N.D.	N.D.	0.16	0.20
2	0.10	0.13	0.11	0.13	0.16	0.16	0.10	0.14	0.21	0.23	0.19	0.24
3	0.14	0.15	0.11	0.14	0.13	0.17	0.10	0.10	0.17	0.22	0.18	0.21
4	0.13	0.15	0.10	0.12	0.15	0.15	0.12	0.13	0.17	0.18	0.18	0.19
Composite	0.13	0.18	0.13	0.21	0.16	0.20	0.13	0.21	0.20	0.26	0.20	0.27
Total Stops[d]	1,031		921		897		1,031		405	676		

[a] Minutes per stop. Study was made prior to distributing bags.

[b] Standard deviation of the travel time between stops.

[c] Not determined.

[d] Total collection stops made during study period.

TABLE 8

INITIAL FIELD SURVEY SIGNIFICANCE TEST – TOTAL ITEMS PER STOP

Week	Mean Number of Items at the Stop		Standard Deviation [a]		Number of Samples		Significance Level, U [b]
	Route A1	Route A2	Route A1	Route A2	Route A1	Route A2	
1	3.98	3.64	2.46	2.50	260	229	1.525
2	3.98	4.07	2.60	2.69	256	222	-0.376
3	3.86	3.76	2.52	2.45	255	227	0.445
4	3.93	4.26	2.44	2.49	260	243	-1.516
Composite	3.94	3.94	2.51	2.54	1,031	921	0.033

[a] Standard deviation of the number of items per stop. Study was made prior to distributing bags.

[b] Rejection number is ± 1.96 at 5% level of significance.

TABLE 9

QUANTITY OF SOLID WASTE PER HOUSEHOLD UNIT[a]

AREA A

	No. Units Collected		Quantity/Unit (lbs)	
Week[b]	Route 1	Route 2	Route 1	Route 2
1	263	258	71.6	62.6
2	259	248	72.2	72.5
3	258	257	68.6	58.0
4	263	267	65.0	69.5
Composite (Area A)	1,043	1,030	69.3	65.6

AREA B

Week	Route 3	Route 4	Route 3	Route 4
1	N.D.[c]	182	N.D.	69.1
2	300	296	61.3	62.8
3	302	259	61.8	58.5
4	295	294	67.6	60.8
Composite (Area B)	897	1,031	63.5	62.3

AREA C

Week	Route 5	Route 6	Route 5	Route 6
1	N.D.	457	N.D.	40.2
2	568	482	32.0	38.9
3	431	476	43.8	39.5
4	516	486	33.1	35.3
Composite (Area C)	1,515	1,901	35.8	38.4

[a] Measured during October of 1968.

[b] Field data was obtained from all study routes during each week for once-a-week collection.

[c] Not determined.

TABLE 10

SOLID WASTE PHYSICAL DATA SAMPLING[a]

	November 1968			February 1969			July 1969		
	Area A	Area B	Area C	Area A	Area B[f]	Area C	Area A	Area B	Area C
Stops Sampled (no.)	17	16	7	16	13	7	17	15	14
Total Sample Wt (lb)	659.0	797.6	572.2	1,474.5	787.5	797.1	1,499.3	872.6	1,885.5
Avg. Solid Waste/Can (lb)[b]	15.0	16.5	20.6	20.8	20.4	23.9	16.7	20.8	23.6
Avg. Can Wt (empty) (lb)	8.5	8.1	11.8	8.1	8.6	10.4	7.4	11.5	10.9
Avg. Item Wt (lb)	7.5	8.7	8.1	25.2	20.2	7.0	21.8	19.3	20.1
Solid Waste Composition[c]									
Class 1 (fibers)	46.3	62.2	61.3	58.5	57.2	64.6	34.7	28.3	58.8
Class 2 (vegetation)	34.3	15.0	7.5	33.3	22.7	15.3	52.7	55.0	12.0
Class 3 (metals)	6.3	7.6	8.3	3.9	5.8	6.3	2.8	2.2	9.4
Class 4 (inerts)	10.3	14.2	16.8	3.3	13.1	12.2	4.5	6.7	15.2
Class 5 (putrescibles)	2.8	1.0	6.1	1.0	1.2	1.6	5.3	7.8	4.6
Moisture Content[e]									
Class 1 (fibers)	9.6	6.9	4.2	30.2	181.4	20.1	76.0	12.8	7.0
Class 2 (vegetation)	137.0	152.0	138.5	134.0	117.2	155.3	99.7	127.4	24.1
Class 3 (metals)	N.D.[d]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Class 4 (inerts)	0.9	2.8	0.4	0.68	0.3	19.7	0.38	0	3.8
Class 5 (putrescibles)	558.9	20.8	233.5	90.7	92.2	72.5	N.D.	N.D.	N.D.
Organic Content[e]	84.2	38.9	88.9	86.5	82.8	83.5	97.6	96.7	98.5
Class 1 (fibers)	84.2	38.9	88.9	86.5	82.8	83.5	97.6	96.7	98.5
Class 2 (vegetation)	67.1	68.1	79.7	55.7	62.9	49.3	66.7	66.3	89.7
Class 3 (metals)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Class 4 (inerts)	90.9	51.5	22.2	5.9	9.7	46.6	8.4	8.2	26.7
Class 5 (putrescibles)	73.3	89.8	79.1	80.0	80.7	86.5	N.D.	N.D.	N.D.

TABLE 10 (Continued)

SOLID WASTE PHYSICAL DATA SAMPLING

[a] Sample size was selected to obtain a 60 percent statistical confidence level.
[b] Weight of solid waste in can, lbs.
[c] Percent, Wet Weight.
[d] Not Determined.
[e] Percent, Dry Weight.
[f] Heavy rainfall during and prior to period of sampling.

TABLE II

PURCHASE SUMMARY

	Manufacturer							
Distribution	Name	Model	Material	Thickness (mil)	Use	Purchase Date	Total Number	Cost ($)
1	St. Regis	PM-40	N.A.[a]	N.A.	Holder	3/26/69	200	each 12.00
	International	Garbax Model A	N.A.	N.A.	"	"	200	8.00
	Mobil	PL9-1302	N.A.	N.A.	"	"	200	8.90
	St. Regis	Handi-Sack	Paper	N.A.	Bag	"	15,000	1,000 96.03
	International	Garbax	"	N.A.	"	"	14,000	92.15
	Mobil	Keepaway	Polyethylene	2.5	"	"	10,000	69.50
	Friedman	Narrow	"	2.5	"	"	6,000	70.49
	Friedman	Wide	"	3.0	Can Liner	"	9,000	136.84
2	St. Regis	Handi-Sack	Paper	N.A.	Bag	7/1/69	10,200	96.03
	International	Garbax	"	N.A.	"	"	10,000	92.15
	Mobil	Keepaway	Polyethylene	2.5	"	"	4,400	69.50
	Wagner		"	3.5	Can Liner	5/13/69	5,000	129.95
3	St. Regis	Handi-Sack	Paper	N.A.	Bag	11/10/69	10,000	96.03
	International	Garbax	"	N.A.	"	"	8,000	92.15
	Mobil	Flamegard	Polyethylene	2.5	"	"	10,000	94.01
	Chase	Drawstring	"	2.5	"	"	14,000	87.36
	Mobil	Luxriliner	"	1.5	Can Liner	"	9,600	55.00
Bin Liner	Bemis	2 cu yd	Polyethylene	2.0	Bin Liner	2/2/70	2,520	347.14
	Bemis	3 cu yd	"	2.0	"	"	3,000	429.42

[a] Not applicable.

TABLE 12

COLLECTION TIME PER STOP

Area	Route	Stops Sampled (No.)	Mean Collection Time Per Stop (min.)	S.D.	Significance Level, U[a]
A	1 (Bags)	761[b]	0.353	0.249	
	1 (Bags)	979[c]	0.448	0.368	
	2 (Cans)	465[c]	0.546	0.362	-4.79
B	3 (Cans)	815[c]	0.621	0.344	
	4 (Bags)	774[b]	0.409	0.333	
	4 (Bags)	1,225[c]	0.514	0.421	6.31
C	5 (Bags)	201[b]	0.648	0.534	
	5 (Bags)	266[c]	0.735	0.616	
	6 (Cans)	256[c]	0.981	0.684	-4.32

[a] Rejection number is ± 1.96 at 5% level of significance. U values are for all stops.

[b] Bag stops only. Data is compiled from 4 weeks of field studies.

[c] All stops.

TABLE 13

AVERAGE COLLECTION TIME SAVINGS PER STOP

Area	Mean Collection Time/Stop (min .) Bag Route	Mean Collection Time/Stop (min .) Can Route	Reduction (min.)	Time Reduction of Can Route (percent)
A	0.353[a]		0.193[a]	35[a]
	0.448[b]	0.546	0.098[b]	18[b]
B	0.409[a]		0.212[a]	34[a]
	0.514[b]	0.621	0.107[b]	17[b]
C	0.648[a]		0.333[a]	34[a]
	0.735[b]	0.981	0.246[b]	25[b]

[a] Stops with bags only.

[b] All stops with all items (bags, cans, and other).

NOTE: The collection time given does not include travel time.

TABLE 14

CONTAINER DATA SUMMARY[a]

	Route	
	A1 (Bags)	A2 (Cans)
Data on Stops Having Cans or Bags and Other Items		
Stops Sampled (No.)	250	222
Average Items/Stop (No.)	3.89	3.23
Average Cans/Stop (No.)	0.66	2.27
Average Bags/Stop (No.)	2.36	0.20
Average Solid Waste Quantity (lb/stop)	70.1	62.8
Collection Time on Route (hr)	3.00	2.83
Man-minutes/Ton[b]	20.5	24.4
Average Time/Stop[c]	0.72	0.765
Data on Stops Having Only Cans or Only Bags		
Route	A1 (Bags)	A2 (Cans)
Stops Sampled (No.)	95	127
Average Cans/Stop (No.)	N.A.[d]	2.44
Average Bags/Stop (No.)	2.82	N.A.

[a] 2/11/70 data.
[b] On route only.
[c] Collection and travel on route only.
[d] Not applicable.

TABLE 15

ENVIRONMENTAL SURVEY SUMMARY

Area	A		B		C	
Route	1	2	3	4	5	6
Container Type	Bags	Cans	Cans	Bags	Bags	Cans
Date of Survey	10-21-69	10-28-69	10-23-69	10-16-69	10-17-69	10-24-69
Stops Sampled (No.)	26	24	25	32	13	21
Total Polyethylene Bags (No.)	47	4	3	54	41	5
Total Large Paper Bags (No.)	18	0	0	15	55	0
Open Polyethylene Bags (No.)	12	N.A.[a]	N.A.	10	7	N.A.
Open Paper Bags (No.)	8	N.A.	N.A.	11	30	N.A.
Polyethylene Bags Open (%)	25.5	N.A.	N.A.	18.5	17.1	N.A.
Paper Bags Open (%)	44.4	N.A.	N.A.	73.3	54.5	N.A.
Spilled Polyethylene Bags (No.)	0	N.A.	N.A.	0	0	N.A.
Spilled Paper Bags (No.)	0	N.A.	N.A.	0	0	N.A.
Total Cans (No.)	3	49	49	20	5	87
Cans - No Lid (No.)	2	31	34	16	5	75
Cans - No Lid (%)	66.7	63.3	69.4	80.0	100.0	86.2

[a] Not applicable.

TABLE 16

FIELD SURVEYS, SOLID WASTE CONTAINERS (NUMBER)[a]

Study Area	A				B				C			
Route	1 (Bags)		2 (Cans)		3 (Cans)		4 (Bags)		5 (Bags)		6 (Cans)	
Week	Mean[b]	S.D.[c]	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	3.77	2.00	3.56	1.96	3.87	2.09	3.96	2.17	6.39	5.50	6.08	3.99
2	3.99	2.26	4.09	2.12	3.99	2.16	4.06	2.20	7.21	5.60	5.89	4.28
3	4.21	2.30	N.D.[d]	N.D.	3.91	2.12	4.31	2.85	7.30	5.65	6.29	4.88
3	4.35	2.46	4.12	2.41	3.87	2.19	4.21	2.44	N.D.	N.D.	N.D.	N.D.
Composite	4.08	2.27	3.93	2.18	3.91	2.14	4.13	2.43	7.13	5.57	6.07	4.39
Total Samples	979		699		1,166		1,120		444		468	

[a] Total items including cans or bags.
[b] Number per stop.
[c] Standard deviation of the number of items per stop.
[d] Not determined.

TABLE 17

SIGNIFICANCE TEST - TOTAL ITEMS PER STOP, AREA A

	Mean Number of Items at the Stop		Standard Deviation[a]		Number of Samples		Significance Level, U[b]
Week	Route A1 Bags	Route A2 Cans	Route A1 Bags	Route A2 Cans	Route A1 Bags	Route A2 Cans	
1	3.77	3.56	2.00	1.96	236	232	1.15
2	3.99	4.09	2.26	2.12	249	238	-0.50
3	4.21	N.D.[c]	2.30	N.D.	249	N.D.	N.D.
4	4.35	4.12	2.46	2.41	245	229	1.03
Composite	4.08	3.93	2.27	2.18	979	699	1.37

[a] Standard deviation of the number of times per stop.

[b] Rejection number is ± 1.96 at 5% level of significance.

[c] Not determined.

TABLE 18

SIGNIFICANCE TEST - TOTAL ITEMS PER STOP, AREA B

Week	Mean Number of Items at the Stop		Standard Deviation[a]		Number of Samples		Significance Level, U[b]
	Route B3 Cans	Route B4 Bags	Route B3 Cans	Route B4 Bags	Route B3 Cans	Route B4 Bags	
1	3.87	3.96	2.09	2.17	304	289	-0.51
2	3.99	4.06	2.16	2.20	301	283	-0.39
3	3.91	4.31	2.12	2.85	300	289	-1.93
4	3.87	4.21	2.19	2.44	261	259	-1.68
Composite	3.91	4.13	2.14	2.43	1,166	1,120	-2.295

[a] Standard deviation of the number of items per stop.

[b] Rejection number is ± 1.96 at 5% level of significance.

TABLE 19

SIGNIFICANCE TEST - TOTAL ITEMS PER STOP, AREA C

Week	Mean Number of Items Per Unit		Standard Deviation[a]		Number of Samples		Significance Level, U[b]
	Route C5 Bags	Route C6 Cans	Route C5 Bags	Route C6 Cans	Route C5 Bags	Route C6 Cans	
1	3.81	2.76	3.10	2.04	141	147	-3.39
2	3.07	2.77	2.24	2.12	179	141	-1.23
Composite	3.39	2.76	2.67	2.08	320	288	-3.27

[a] Standard deviation of the number of items per unit.

[b] Rejection number is ± 1.96 at 5% level of significance.

TABLE 20

FIELD CONTAINER WEIGHTS

Container Type	Samples (No.)	Full (lb)	Empty (lb)	Net (lb)	Utilized Capacity[h] (%)	Estimated Net Weight of Full Container (lb)
Paper Bag[a]	75	19.5	0.5	19.1	79.8	23.9[b]
Polyethylene Bag[c] (2.5 mil)	74	15.4	0.1	15.3	75.3	20.4
Polyethylene Drawstring Bag[d] (2.5 mil)	37	14.7	0.1	14.6	88.0	16.6
Polyethylene Can Liner[e] (1.5 mil)	27	15.1	0.1	15.0	77.6	19.3
Polyethylene Can Liner[f] (3.0 mil)	58	24.2	0.1	24.1	74.7	32.3
Cans[g]	197	33.2	9.7	23.5	91.2	25.8

[a] Thickness not applicable. 35 gal size packed free-hanging.

[b] Estimated net weight of full container = $\frac{\text{Net (lb)}}{\text{Utilized Capacity (\%)}}$

[c] 32 gal size packed free-hanging.

[d] 20 gal size packed free-hanging.

[e] 45 gal size liner installed in a 32 gal can and packed as free-hanging.

[f] 45 gal size packed free-hanging.

[g] 32 gal size.

[h] Bag capacities are based on the volume available when the bags are closed.

TABLE 21

FIELD SURVEY WASTE COLLECTION AT BRIARWOOD CONDOMINIUM, INGLEWOOD, CALIFORNIA

Item	April 29, 1970	May 27, 1970
Number of condominium units serviced	366[a]	430
Number of service stops	195	315
Collection time, minutes	83.5	157.7
Travel time, minutes	25.7	46.3
Number of items collected	739	764
Number of bags collected	406	466
Number of paper bags collected	N.D.[b]	324
Number of polyethylene bags collected	N.D.	142
Number of cans collected	165	182
Number of boxes collected	69	46
Number of bundles collected	28	30
Number of sacks collected	71	40
Number of paper bags on holders	N.D.	36
Number of polyethylene bags on holders	N.D.	9
Lost time, minutes	7.01	22.1

Continued . . .

TABLE 21 (Continued)

FIELD SURVEY WASTE COLLECTION AT BRIARWOOD CONDOMINIUM, INGLEWOOD, CALIFORNIA

Item	April 29, 1970	May 27, 1970
Number of spills	N.D.	7
Average number of condominium units collected per stop	1.88	1.37
Average number of items collected per stop	3.79	2.42
Average number of items per condominium unit	2.02	1.77
Average collection time per stop, minutes	.430[a]	.500
Average collection time per condominium unit, minutes	.346[a]	.366
Average travel time per stop, minutes	.137	.147
Average travel time per unit collected, minutes	.111	.108

[a] Of this total, 241 units were used to determine collection times.

[b] Not determined.

TABLE 22

SOUND MEASUREMENTS

Distance from Source (ft)	Mean Readings on Scale A (db) Background	Vehicle Motor	Banging Cans	Vehicle Packer
2	58.8	96.9	95.5	92.0
10	63.6	87.7	85.6	83.8
50	58.3	76.8	81.1	74.5
100	53.5	70.0	75.0	66.0

TABLE 23

CONSTANTS FOR USE IN THE NOISE RATING FORMULA

Mid-Frequency of Octave Band (cps)	a (db)	b (db)
500	4.8	0.974
1000	0	1.00
2000	-3.5	1.015

TABLE 24

NOISE RATING NUMBERS - FIELD TESTS

Distance from Source (ft)	Background	Vehicle Packer/Motor[a]	Banging Cans
2	50	88	86
10	57	77	82
50	57	70	72

[a] The rating number entered is either the Packer or Motor number, whichever was highest.

TABLE 25

NOISE RATING NUMBERS[a]- LABORATORY TESTS

Distance from[b] Source (ft)	Drop[c] Height (ft)	Metal Can	Polyethylene Bag	Paper Bag
35	2	81	53	57
35	3	82	58	59

[a] The numbers presented in the table are for asphalt which produced the greatest noise.

[b] A distance of 35 ft was chosen because it was equivalent to the average distance from the cans at the curb to the nearest room in residences on the demonstration routes.

[c] For containers.

TABLE 26

FREQUENCY DISTRIBUTION OF NUMBER OF LARVAE MIGRATING FROM SOLID WASTE CONTAINERS

Number of Larvae Collected During 8-Week Study	Containers Without Polyethelene Liners (No.)	Containers Without Polyethelene Liners (%)	Containers With Polyethelene Liners (No.)	Containers With Polyethelene Liners (%)
0	14	24	18	35
1-100	14	24	14	27
101-1,000	22	37	11	21
1,001-10,000	8	13	9	17
10,000	1	2	0	0
Total	59	100	52	100

Source: Reference 10.

TABLE 27

FREQUENCY DISTRIBUTION OF NUMBER OF WEEKS MORE THAN TWENTY LARVAE MIGRATED FROM SOLID WASTE CONTAINERS

Number of Weeks With More Than 20 Larvae Migrating from Solid Waste Containers	Containers Without Polyethelene Liners		Containers With Polyethelene Liners	
	(No.)	(%)	(No.)	(%)
0	18	30	23	39
1	18	30	12	28
2	14	24	8	16
3	1	2	4	7
4	3	5	2	4
5	4	7	0	0
6	0	0	2	4
7	0	0	1	2
8	1	2	0	0
Total	59	100	52	100

Source: Reference 10.

TABLE 28

STREET LITTER INDICES

Observation Number	Area	Street	Litter Index[a] Before Collection	After Collection
1	A1	Fairview	15.5	0
		64th	62.5	0
	B3	Thoreau	0	0
		111th	0	0
	B4	Ardath	55.1	0
		Chanera	19.9	0
2	B3	Thoreau	24.5	0
		11th	47.9	0
	B4	Ardath	93.1	0
		Chanera	25.1	0
	C5	Hill	15.0	0
		Short	0	0
	C6	Plymouth (1)	81.0	0
		Plymouth (2)	44.7	43.4
3	B3	Thoreau	145.8	0
		11th	84.6	0
	B4	Ardath	37.8	0
		Chanera	58.4	0
	C5	Hill	0	0
		Short	92.6	0
	C6	Plymouth (1)	106.0	0
		Plymouth (2)	244.8	167.8
4	B3	Thoreau	34.0	0
		11th	88.5	0
	B4	Ardath	15.5	0
		Chanera	42.6	0
	C5	Hill	15.4	0
		Short	96.7	0
	C6	Plymouth (1)	46.6	0
		Eucalyptus	54.2	0

Continued . . .

TABLE 28 (Continued)

STREET LITTER INDICES

Observation Number	Area	Street	Litter Index[a] Before Collection	After Collection
5	Briarwood	Chelsea (1)	0	0
		Chelsea (2)	0	0
		Kensington (1)	0	0
		Kensington (2)	0	0
		Markham	3.9	2.0
		Featherstone	3.3	3.9

[a] The litter index is defined as the sum of surface areas (one side only) of all pieces of litter in the 1,000 sq ft test zone.

TABLE 29

LITTER INDEX - BAGS VS. CANS

Bag Route Collection			Can Route Collection			
Before		After	Before		After	
Items, No.	Area, sq in.	Items, No.	Items, No.	Area, sq in.	Items, No.	Area, sq in.
3	15.5	0	6	34.0	0	0
5	62.5	0	2	88.5	0	0
3	19.9	0	3	24.5	0	0
5	55.1	0	12	47.9	0	0
4	15.5	0	7	81.0	0	0
5	42.6	0	5	44.7	4	43.4
4	15.4	0	9	145.8	0	0
10	96.7	0	6	84.6	0	0
0	0	0	0	0	0	0
9	92.6	0	0	0	0	0
6	93.1	0	10	106.0	0	0
3	25.1	0	9	244.8	2	167.8
2	15.0	0	12	46.6	0	0
0	0	0	5	54.2	0	0
2	37.8	0				
4	58.4	0				
Totals: 65	645.2	0	86	1002.6	6	211.2
Avg.: 4.1	40.3	0	6.1	71.6	0.4	15.0

TABLE 30

SUMMARY OF RESPONSES TO BIN LINER QUESTIONNAIRE[a]

Item	Response	
	Yes	No
Improvements		
Fly problem	8	6
Odor control	10	4
Bin cleanliness	12	2
Reduction of frequency of need to clean bin	14	0
Difficulties		
Installing liner into bin	6	8
Do you clean bin regularly?	8	6
Did you like the bin liners?	14	0
Should the City encourage bin liner use?	14	0

[a] Total number of questionnaires returned was 14.

TABLE 31

SUMMARY OF COMMENTS TO BIN LINER QUESTIONNAIRE[a]

Comment	Number of Respondents
Positive	
Improvement in operation	4
More sanitary	1
Saves maintenance	1
Total positive comments	6
Negative	
Liners too small, therefore, hard to install	3
Need two people to fit liner	2
Collector should install liner	1
Total negative comments	6

[a] Total number of questionnaires returned was 14.

TABLE 32

COMPARISON OF BIN COLLECTION TIME: WITH AND WITHOUT LINERS

Task by Sequence	Average time/task (min) With liner[a]	 Without liner[b]
Unhook liner from bin	0.21	0.0
Lifting bin on forkhook	0.10	0.10
Dump bin	0.11	0.10
Lowering bin	0.10	0.09
Total	0.52	0.29

[a] 15 samples
[b] 16 samples

TABLE 33

POLYETHYLENE BIN LINER COST ANALYSIS[a]

Cost Items								
Extra Collection Cost with liners		Liner Cost		Bin Cost			Cleaning Cost[b] $/bin/yr	
$/bin/service	$/restaurant/yr	$/liner	$/restaurant/yr	$/bin	$/bin/service	$/restaurant/yr	with liner	without liner
0.0414	14.20	0.75	257.00	190.00	0.0369	12.66[c]	20	40
					0.0554	19.00[d]		

Incremental Cost Per Restaurant Per Year (Excludes normal collection costs): With liners - $303.86; Without liners - $59.00.

[a] Costs based on an average of 6.6 services/restaurant/week estimated from the field survey for 3 cu yd bins and 2.0 mil liners.

[b] Estimated from current (1970) costs of $80 for cleaning one bin two (2) times per year.

[c] Assuming a 15-year bin life using liners.

[d] Assuming a 10-year bin life without liners.

TABLE 34

CAN COLLECTION DUST SAMPLES

Date:	January 7, 1970
Truck No.:	152
Weather:	overcast
Location:	102nd Street and Prairie Avenue, Inglewood
Sampling Location:	5 ft above ground near hopper
Wind:	slight breeze blowing across truck from south-southeast
Containers:	cans

TABLE 35

BAG COLLECTION DUST SAMPLES

Date:	January 27, 1970
Truck No.:	128
Weather:	cool and overcast
Location:	Eucalyptus Avenue and Fairview Boulevard (Study Route A1), Inglewood
Sampling Location:	5 ft above ground near hopper
Wind:	very slight breeze from the east
Containers:	bags

TABLE 36

PLATE COUNTS FOR MICROORGANISMS FROM CAN COLLECTION DUST SAMPLES

	Colony Counts[c]			
	Bacteria		Fungi	
Plate No.	24 Hours	48 Hours	24 Hours	48 Hours
1[a]	0	1	0	0
2	65	300	85	370
3	1000	(2500)[b]	800	(2600)[b]
4	320	(800)[b]	100	(325)[b]
5	350	500	110	200
6	30	90	45	110
7	375	(940)[b]	125	(400)[b]
8[a]	90	160	0	0
9	100	170	35	80
10	75	150	50	170
11	100	140	20	35
12	40	60	10	35
13	10	30	0	0
14	5	15	3	5
15	20	70	15	100
16[a]	70	70	0	0
17	30	80	50	130
18	15	55	10	40
19	60	120	10	50
20	25	60	90	200
21	100	230	90	160
22	65	140	50	130
23	500	(1250)[b]	80	(260)[b]
24	550	(1375)[b]	60	(195)[b]
25	200	(500)[b]	160	(520)[b]
26	15	40	10	70
27	120	250	30	50
28	75	(190)[b]	60	(195)[b]
29	20	50	10	40
30[a]	0	20	0	2

[a] Background samples.

[b] Values based on average rate of increase of all other countable plates; these plates were uncountable at 48 hrs due to quantity of growth. Diameter of test plate, 100 mm.

[c] Microbic media plate counts were made following 68°F incubation.

TABLE 37

PLATE COUNTS FOR MICROORGANISMS FROM BAG COLLECTION DUST SAMPLES

	Colony Counts[b]			
	Bacteria		Fungi	
Plate No.	24 Hours	48 Hours	24 Hours	48 Hours
1[a]	0	0	0	0
2	0	3	0	7
3	1	4	0	10
4	0	3	0	0
5	0	20	0	60
6	10	15	0	30
7	1	40	1	25
8	0	3	0	4
9	0	2	0	3
10[a]	0	0	0	1
11	0	0	0	1
12	1	4	0	30
13	0	2	0	12
14	0	5	0	35
15	0	1	0	5
16	5	15	3	80
17	0	1	0	10
18	1	6	0	5
19	1	2	0	10
20[a]	0	0	0	0
21	3	20	0	30
22	2	10	0	5
23	0	1	0	2
24	7	15	0	70
25	0	0	0	0
26	1	20	0	100
27	0	5	0	12
28	0	8	0	15
29	2	5	0	2
30[a]	0	0	0	0

[a] Background.

[b] 100 mm diameter test plate incubated at 68°F prior to plate counts.

TABLE 38

NUMBER OF COLONIES PER PLATE[a]

	Average Count							
	Bacteria				Fungi			
	Background		Collection Vehicle Sample		Background		Collection Vehicle Sample	
	24 hr	48 hr	24 hr	48 hr	24 hr	48 hr	24 hr	48 hr
Cans	40	63	164	389[b]	0	0.25	81	249[b]
Bags	0	0	1.4	8.1	0	0	0.15	21.7

[a] 100 mm diameter plate.

[b] Values based on extrapolations.

TABLE 39

LIST OF GROUP AND GENERA OF A FEW BACTERIA ISOLATED FROM TEST CAN COLLECTION PLATES

Test Plate #	Gram Reaction	Morphology	Arrangement of Cells	Hemolysis	Genus
5	+	Spherical	Chains	+	*Streptococcus*
8[a]	+	Spherical	Clusters	-	*Staphylococcus*
7	+	Budding Cells	Group of 2 to 3	-	*Yeast*
9	+	Spherical	Pairs of two cells	+	*Diplococcus*
9	-	Rods	Individual and chains of 3-5 cells	-	Gram negative rod
10	-	Rods	Short Chains	-	Gram negative rod
10	-	Thin long rods	Pairs of 2-3	-	Gram negative rod
11	-	Rods	Single, Paired	-	Gram negative rod
12	-	Rods	Single, Paired	-	Gram negative rod
13	+	Spherical	Clusters	+	*Staphylococcus*
14	+	Rods	Chained, spore forming	-	*Bacillus*
15	-	Rods	Single, Pairs	-	Gram negative rod
15	+	Rods	Chains, spore forming	-	*Bacillus*
15	+	Spherical	Pairs of two	+	*Diplococcus*
15	+	Spherical	Clusters	+	*Staphylococcus*
16[a]	+	Rods	Chains, spores	-	*Bacillus*
17	-	Short rods	Chains of 4-6 cells	-	Gram negative rod
18	-	Short rods	Single, Pairs	-	Gram negative rod
18	+	Spherical	Chains	-	*Streptococcus*
18	+	Budding cells	Individual	-	*Yeast*
18	+	Spherical	Clusters	-	*Staphylococcus*
21	+	Spherical	Chains	+	*Streptococcus*
23	+	Spherical	Pairs of 2	+	*Diplococcus*
25	-	Short Rods	Individual	+	*Hemophilus*
26	-	Rods	Short Chains	-	Gram negative rod
26	-	Rods	Short Chains	-	Gram negative rod
26	+	Spherical	Chains	+	*Streptococcus*
27	+	Spherical	Chains	+	*Streptococcus*
30[a]	+	Rods	Chains, spores	-	*Bacillus*
1[a]	+	Rods	Chains, spores	-	*Bacillus*

[a] Background samples.

TABLE 40

FILAMENTOUS FUNGI ISOLATED FROM CAN COLLECTION TEST PLATES

Plate Number	Genus of Fungi
2	*Penicillium*
5	*Aspergillus*
	Penicillium
	Chaetomium
7	*Gymenoascus*
	Penicillium
	Chaetomium
10	Mycelia sterilia
	Penicillium
	Mucor
13	*Trichotheceiem*
	Rhiquopus
	Aspergillus
	Penicillium
15	*Penicillium*
	Aspergillus
18	*Rhizopus*
	Penicillium
19	*Cylindrocarpon*
	Chaetomium
	Penicillium
	Aspergillus
22	*Microsporum*
	Aspergillus
	Penicillium
27	*Rhizopus*
	Mucor
	Penicillium

TABLE 41

MAJOR DISEASES CAUSED BY YEAST-LIKE MICROORGANISMS[a]

Disease	Organism	Remarks
Cryptococcosis	Cryptococcus Neoformaus	Generally ulcers on skin, spreading to blood stream or nervous system.
Blastomycosis	Blastomysis dermatitidis	Infects skin and lungs.
Candidiasis	Candica albicans	Infects skin, nails, mucous membranes, lungs.

[a] No project tests showed these organisms.

TABLE 42

QUESTIONNAIRE 2: RESPONSES BY BAG SYSTEM

Bag System	Private Residents	Apartment Dwellers	Total
St. Regis Paper Bag with Holder	142	12	154
Mobil Keepaway and Friedman Narrow Polyethylene Bags with Holders	109	5	114
International Paper Bag with Holder	114	0	114
Friedman Wide Polyethylene Can Liner	89	32	121
St. Regis Paper Bag without Holder	32	1	33

TABLE 43

QUESTIONNAIRE 3: RESPONSES BY BAG SYSTEM

	Number of Responses		
Bag System	Private Residents	Apartment Dwellers	Total
St. Regis Paper Bag with Holder	100	2	102
Mobil Keepaway Polyethylene Bag with Holder	95	3	98
International Paper Bag with Holder	81	5	86
Wagner Polyethylene Can Liner	94	30	124

TABLE 44

SUMMARY OF RESPONSES TO QUESTIONNAIRE 1 (PRE-TEST QUESTIONNAIRE)

Question	Total Responses (No.)	Responses (No.)					Responses (%)	
		Never	Occasionally	Sometimes	Frequently	Always	Never	Always
Did you ever see spilled refuse in the streets on your collection day?	830	386	294	84	47	19	46	2
Did you ever see flies or ants in your trash cans?	853	439	255	110	41	8	51	1
Did you ever find it difficult or inconvenient to carry emptied trash cans from the curb to your storage area?	834	596	108	55	25	50	71	6
Does the collector ever leave small amounts of refuse in trash cans?	859	329	332	119	60	19	38	2
How often are your trash cans damaged by the collector?	842	315	280	105	98	44	37	5
Do you ever smell unpleasant odors in your trash cans?	834	370	275	121	52	16	44	2
How often do you feel the appearance of your neighborhood is less attractive when trash cans are at the curb on collection day?	815	270	137	93	57	258	33	32

TABLE 45

COMBINED SUMMARY OF RESPONSES TO QUESTIONNAIRES 2 AND 3

	Mobil[a] & Holder (212)[d]		St. Regis[b] & Holder (256)[d]		International[b] & Holder (200)[d]		Can Liner[c] (245)[d]		St. Regis[b] No Holder (36)[d]		Total (949)[d]	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Improvements												
Holder and bag more attractive than conventional solid waste containers	158	46	211	36	151	33	N.A.[e]	N.A.	N.A.	N.A.	520	115
Neighborhood appearance	162	33	213	29	154	30	206	25	29	3	764	119
Collection noise	143	48	187	44	130	43	168	53	23	5	651	193
Odor conditions	120	64	168	58	115	62	155	62	17	9	585	255
Fly problem	108	74	167	60	115	64	145	72	18	10	553	280
Spillage problem	124	61	166	60	111	59	173	46	16	12	590	238
Difficulties												
Mounting bag or liner	76	131	42	210	22	170	8	108	5	16	153	635
Placing solid waste in bag	97	111	28	223	33	150	22	180	8	21	188	705
Closing bag	71	134	65	178	60	128	57	169	13	21	266	630
Carrying bags to curb	10	187	23	121	26	162	43	190	5	29	107	789
Did holder lid function satisfactorily	142	70	181	60	174	16	N.A.	N.A.	N.A.	N.A.	497	146
Tipping over of holder	32	172	19	228	17	176	N.A.	N.A.	N.A.	N.A.	68	576
never	55		127		95		119		16		412	
Bags failed occasionally	110		101		73		112		18		414	
frequently	32		14		14		9		3		72	
Primary causes of failure												
Sharp objects	122		52		48		111		9		344	
Wet solid waste	13		42		48		8		8		119	
Heavy solid waste	45		11		15		27		6		104	
Animal damage	46		59		46		30		7		188	
Rough handling	9		1		2		11		2		25	
Did you like the system	137	53	210	32	151	31	212	20	28	5	738	141

Continued . . .

TABLE 45 (Continued)

COMBINED SUMMARY OF RESPONSES TO QUESTIONNAIRES 2 AND 3

[a] Mobil Keepaway (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] Combined responses for the Friedman Wide (3.0 mil) polyethylene can liner (Questionnaire 2) and the Wagner (3.5 mil) polyethylene can liner (Questionnaire 3).
[d] Figures in brackets give number of questionnaires returned.
[e] Not applicable.

TABLE 46

COMBINED SUMMARY OF RESPONSES TO QUESTIONNAIRES 2 AND 3 (Expressed in Percentages)

	Mobil[a] & Holder			St. Regis[b] & Holder			International[b] & Holder		
	Yes	No	N.R.[d]	Yes	No	N.R.	Yes	No	N.R.
Improvements									
Holder and bag more attractive than conventional solid waste container	74.5	21.7	3.8	82.4	14.1	3.5	75.5	16.5	8.0
Neighborhood appearance	76.4	15.6	8.0	83.2	11.3	5.5	77.0	15.0	8.0
Collection noise	67.5	22.6	9.9	73.0	17.2	9.8	65.0	21.5	13.5
Odor conditions	56.6	30.2	13.2	65.6	22.7	11.7	57.5	31.0	11.5
Fly problem	50.9	34.9	14.2	65.2	23.4	11.4	57.5	32.0	10.5
Spillage problem	58.5	28.8	12.7	64.8	23.4	11.8	55.5	29.5	15.0
Difficulties									
Mounting bag or liner	35.8	61.8	2.4	16.4	82.0	1.6	11.0	85.0	4.0
Placing solid waste in bag	45.8	52.4	1.9	10.9	87.1	2.0	16.5	75.0	8.5
Closing bag	33.5	63.2	3.3	25.4	69.5	5.1	30.0	64.0	6.0
Carrying bags to curb	4.7	88.2	7.1	9.0	47.3	43.7	13.0	81.0	6.0
Did holder lid function satisfactorily	67.0	33.0	0	70.7	23.4	5.9	87.0	8.0	5.0
Tipping over of holder	15.1	81.1	3.8	7.4	89.1	3.5	8.5	88.0	3.5
Bags failed never		25.9			49.6			47.5	
occasionally		51.9			39.5			36.5	
frequently		15.1			5.5			7.0	
Primary causes of failure[f]									
Sharp objects		51.9			31.5			30.2	
Wet solid waste		5.5			25.5			30.2	
Heavy solid waste		19.1			6.7			9.4	
Animal damage		19.6			35.8			28.9	
Rough handling		3.9			0.5			1.3	
Did you like the system	64.6	25.0	10.4	82.0	12.5	5.5	75.5	15.5	9.0

Continued . . .

TABLE 46 (Continued)

COMBINED SUMMARY OF RESPONSES TO QUESTIONNAIRES 2 AND 3 (Expressed in Percentages)

	Can Liner[c]			St. Regis,[b] No Holder			Total		
	Yes	No	N.R.	Yes	No	N.R.	Yes	No	N.R.
Improvements									
Holder and bag more attractive than conventional solid waste container	N.A.[e]	N.A.	N.A.	N.A.	N.A.	N.A.	77.8	17.2	5.0
Neighborhood appearance	84.1	10.2	5.7	80.6	8.3	11.1	80.5	12.5	17.5
Collection noise	68.6	21.1	9.8	63.9	13.9	22.2	68.6	20.3	11.1
Odor conditions	63.3	25.3	11.4	47.2	25.0	27.8	61.6	26.9	11.5
Fly problem	59.2	29.4	11.4	50.0	25.0	25.0	58.3	29.5	12.2
Spillage problem	70.6	18.8	10.6	44.4	33.3	22.3	62.2	25.1	12.7
Difficulties									
Mounting bag or liner	3.3	44.1	52.7	13.9	44.4	71.7	16.1	66.9	17.0
Placing solid waste in bag	9.0	73.5	17.6	22.2	58.3	19.5	19.8	74.3	5.9
Closing bag	23.3	69.0	7.7	36.1	58.3	5.6	28.0	66.4	5.6
Carrying bags to curb	17.6	77.6	4.8	13.9	80.6	5.5	11.3	83.1	5.6
Did holder lid function satisfactorily	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	74.4	21.9	3.7
Tipping over of holder	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	10.2	86.2	3.6
Bags failed never		48.6			44.4			43.4	
Bags failed occasionally		45.7			50.0			43.6	
Bags failed frequently		3.7			8.3			7.6	
Primary causes of failure[f]									
Sharp objects		59.4			28.1			44.1	
Wet solid waste		4.3			25.0			15.3	
Heavy solid waste		14.4			18.8			13.3	
Animal damage		16.0			21.9			24.1	
Rough handling		5.9			6.2			3.2	
Did you like the system	86.5	8.2	5.3	77.8	13.9	8.3	77.8	14.9	7.3

TABLE 46 (Continued)

COMBINED SUMMARY OF RESPONSES TO QUESTIONNAIRES 2 AND 3
(Expressed in Percentages)

[a] Mobil Keepaway (2.5 mil) polyethylene bag.

[b] Paper bag.

[c] Combined responses for the Friedman Wide (3.0 mil) polyethylene can liner (Questionnaire 2) and the Wagner (3.5 mil) polyethylene can liner (Questionnaire 3).

[d] No response.

[e] Not applicable.

[f] Percentages are based on total number of failure types reported.

TABLE 47

SUMMARY OF COMMENTS FROM QUESTIONNAIRES 2 AND 3

Comments	Bag System Mobil[a] & Holder	St. Regis[b]	International[c] & Holder	Can Liner[d]	Total
Positive					
Cleaner	14	16	15	19	64
Easy to use	7	14	8	7	36
Unlimited supply of containers	2	5	1	8	16
Better area appearance	10	7	12	20	49
No can carrying to curb and back	13	15	19	14	61
Less noise	2	4	3	5	14
Less odor	0	2	1	6	9
Less flies	1	0	0	0	1
Easy to carry	1	0	0	1	2
Able to locate near door	0	0	1	0	1
Saves cans	N.A.[e]	N.A.	N.A.	3	3
Capacity	0	0	0	7	7
Keeps cans clean	N.A.	N.A.	N.A.	4	4
Very positive comments	5	18	14	21	58
Total Positive Comments	55	81	74	115	325
Negative					
Had bag closure problem	9	9	9	13	40
Opening too small	14	3	11	0	28
Problem with yard solid waste	15	7	14	4	40
Problem with lid	26	2	0	N.A.	28
Problem changing bags	5	4	1	1	11
Problem with animal damage	5	9	7	9	29
System awkward	4	4	1	1	10
Problem placing solid waste in bag	2	0	2	0	4
Had ant problem	1	4	7	1	13

Continued . . .

TABLE 47 (Continued)

SUMMARY OF COMMENTS FROM QUESTIONNAIRES 2 AND 3

	Bag System				
Comments	Mobil[a] & Holder	St. Regis[b]	International[c] & Holder	Can Liner[d]	Total
Bag too small	10	1	4	0	15
Storage problem	0	2	1	2	5
Fly problem	0	1	2	3	6
Spillage problem	0	1	0	0	1
Container system hard to move	0	2	0	0	2
Bags too flimsy	5	0	0	2	7
Odor problem	3	0	0	0	3
Maggots in bag	2	0	0	0	2
Bags will not stay on holder	21	0	0	N.A.[e]	21
Difficulty removing bag from holder	0	0	1	N.A.	1
Rats attacked bag	2	0	0	0	2
Lifting bag from can	N.A.	N.A.	N.A.	10	10
Bag slides into can	N.A.	N.A.	N.A.	3	3
Bag hard to carry	0	0	0	2	2
Causes extra work or time	1	0	0	5	6
Bag slippery	0	0	0	1	1
Concerned about rain on paper bags	N.A.	8	8	N.A.	16
Green dye runs	0	2	N.A.	0	2
Concerned about cost	15	11	7	17	50
Container tipped over	0	0	1	0	1
Very negative comments	1	3	2	4	10
Total Negative Comments	139	65	71	77	368

[a] Mobil Keepaway (2.5 mil) polyethylene bag.

[b] Paper bags with and without holders.

[c] Paper bag.

[d] Combined responses for the Friedman Wide (3.0 mil) polyethylene can liner (Questionnaire 2) and the Wagner (3.5 mil) polyethylena can liner (Questionnaire 3).

[e] Not applicable.

TABLE 48

SYSTEM COMPARISONS [a]

	Bag System			
Attribute	Mobil[b] & Holder	St. Regis[c] & Holder	International[c] & Holder	Can Liner[d]
Ease of Mounting Bag on Holder	6.9/5.5	8.6/7.8	9.5/8.3	N.A.[e]
Ease of Placing Solid Waste in the Bag	6.1/4.5	8.9/9.0	8.5/8.0	9.3/8.4
System Attractiveness re: Cans/Bags	7.9/7.7	8.6/8.5	8.3/8.4	N.A.
Holder Stability	9.4/7.2	9.5/8.9	9.3/9.1	N.A.
Satisfaction with Holder Lid Operation	4.9/3.9	9.7/8.9	9.4/8.9	N.A.
Infrequency of Failure	2.9/2.6	5.6/4.8	5.1/5.0	5.2/4.7
Reduction in Noise	7.5/7.5	7.6/8.9	7.8/7.3	7.3/7.7
Reduction in Odor	6.7/6.3	7.4/7.5	6.3/6.8	7.6/6.8
Reduction in Flies	5.9/5.9	7.4/7.4	6.7/6.1	7.0/6.5
Reducing Spillage	6.7/6.8	7.1/7.8	6.1/7.2	8.5/7.5
Improvement in Neighborhood Appearance	8.7/7.9	8.7/9.1	8.8/8.1	9.2/8.7
Ease in Closing Bag	7.2/5.8	7.3/7.4	7.5/6.2	7.6/7.4
East of Carrying Filled Bag	9.6/9.5	9.0/9.2	8.8/8.5	8.2/8.2
Acceptability of System	7.4/7.0	8.4/9.1	8.4/8.6	9.4/8.9
Average	7.0/6.3	8.1/8.2	7.9/7.6	7.9/7.5

[a] Numbers are derived from questionnaire responses of Inglewood residents. The maximum and best number possible would be 10. The minimum and worst number would be 0. The first number was derived from residents comparing the system to their conventional containers. The second number was derived when residents compared the system to other systems.

[b] Mobil Keepaway (2.5 mil) polyethylene bag.

[c] Paper bag.

[d] Combined results for Friedman Wide (3.0 mil) polyethylene can liner (Questionnaire 2) and Wagner (3.5 mil) polyethylene can liner (Questionnaire 3).

[e] Not applicable.

TABLE 49

SUMMARY OF RESPONSES TO QUESTIONNAIRE 4 (BRIARWOOD CONDOMINIUM QUESTIONNAIRE)

	Mobil[a] & Holder (111)[b]		St. Regis[c] & Holder (110)		International[c] & Holder (109)		Total (330)	
	Yes	No	Yes	No	Yes	No	Yes	No
Improvements								
Holder and bag more attractive than conventional solid waste container	81	17	82	26	78	30	241	73
Neighborhood appearance	78	17	81	21	67	28	226	66
Collection noise	78	15	80	20	53	38	211	73
Odor conditions	64	22	64	33	48	39	176	94
Fly problem	47	27	50	36	37	48	134	111
Spillage problem	61	22	62	35	44	44	167	101
Difficulties								
Tipping over of holder	2	98	4	98	3	106	9	302
Mounting bag	3	96	23	87	18	91	44	274
Placing solid waste in bag	5	93	7	103	15	91	27	289
Closing bag	12	84	14	94	25	80	49	258
Storing bag before use	2	94	30	76	40	65	72	235
Did holder lid function satisfactorily	84	8	97	6	95	12	276	26
Did bags fail often	3	91	7	100	4	102	14	293
Primary causes of failure								
Sharp objects	26		7		6		39	
Wet solid waste	0		3		4		7	
Heavy solid waste	3		2		3		8	
Animal damage	0		3		0		3	
Rough handling	4		2		0		6	
Did you like the system	88	8	91	12	83	21	262	41

[a] Mobil Flamegard (2.5 mil) polyethylene bag.
[b] Figures in parentheses give number of questionnaires returned.
[c] Paper bag.

TABLE 50

SUMMARY OF RESPONSES TO QUESTIONNAIRE 4 (BRIARWOOD CONDOMINIUM QUESTIONNAIRE)
(Expressed in Percentages)

	Mobil[a] & Holder			St. Regis[b] & Holder			International[b] & Holder			Total		
	Yes	No	N.R.[c]	Yes	No	N.R.	Yes	No	N.R.	Yes	No	N.R.
Improvements												
Holder and bag more attractive than conventional solid waste container	73.0	15.3	11.7	74.5	23.6	1.9	71.6	27.5	0.9	73.0	22.1	4.9
Neighborhood appearance	70.3	15.3	14.4	73.6	19.1	7.3	61.5	25.7	12.8	68.5	20.0	11.5
Collection noise	70.3	13.5	6.2	72.7	18.2	9.1	48.6	34.9	16.5	63.9	22.1	13.9
Odor conditions	57.7	19.8	22.5	58.0	30.0	12.0	44.0	35.8	20.2	53.3	28.5	18.2
Fly problem	42.3	24.3	33.4	45.5	32.7	21.8	33.9	44.0	22.1	40.6	33.6	25.8
Spillage problem	55.0	19.8	25.2	56.4	31.8	11.8	40.4	40.4	19.2	50.6	30.6	18.8
Difficulties												
Tipping over of holder	1.8	88.3	9.9	3.6	89.1	7.3	2.8	97.2	0.0	2.7	91.5	5.8
Mounting bag	2.7	86.5	10.8	20.9	79.1	0.0	16.5	83.5	0.0	13.3	83.0	3.7
Placing solid waste in bag	4.5	83.8	11.7	6.4	93.6	0.0	13.8	83.5	2.8	8.2	87.6	4.2
Closing bag	10.8	75.7	13.5	12.7	85.5	1.8	22.9	73.4	4.7	14.8	78.2	7.0
Storing bag before use	1.8	84.7	13.5	27.2	69.2	3.6	36.7	59.6	4.6	21.8	71.2	7.0
Did holder lid function satisfactorily	75.7	7.2	17.1	88.2	5.5	6.3	87.2	11.0	1.8	83.6	7.9	8.5
Did bags fail often	2.7	82.0	15.3	6.4	90.9	2.7	3.7	93.6	2.7	4.2	88.8	7.0
Primary causes of failure[d]												
Sharp objects		78.8			41.2			46.2			61.9	
Wet solid waste		0.0			17.6			30.8			11.1	
Heavy solid waste		9.1			11.8			23.1			12.7	
Animal damage		0.0			17.6			0.0			4.8	
Rough handling		12.1			11.8			0.0			9.5	
Did you like the system	79.3	7.2	13.5	82.7	10.9	6.4	76.1	19.3	4.6	79.4	12.4	8.2

Continued . . .

TABLE 50 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 4 (BRIARWOOD CONDOMINIUM QUESTIONNAIRE)

(Expressed in Percentages)

[a] Mobil Flamegard (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] No response.
[d] Percentages are based on total number of failure types reported.

TABLE 51

SUMMARY OF COMMENTS FROM QUESTIONNAIRE 4 (BRIARWOOD CONDOMINIUM QUESTIONNAIRE)

Comments	Bag System Mobil[a] & Holder (111)[b]	St. Regis[c] & Holder (110)	International[c] & Holder (109)	Total (330)
Positive				
No cans to carry out and back	1	0	2	3
Wish to continue system	13	37	27	77
Decomposes at the dump	1	0	0	1
No empty cans to publicize absence	0	1	2	3
Efficient for City and homeowner	1	2	2	5
Easy to use	4	0	0	4
No cans to clean	2	0	0	2
More sanitary	5	4	5	14
Prefer polyethylene bags	0	2	4	6
How to obtain more	17	0	0	17
Compliment department	3	0	0	3
Save wear and tear on truck	2	0	0	2
Total Positive Comments	49	46	42	137
Negative				
Too small/weak/thin	3	1	4	8
Difficult to seal	0	3	0	3
Too expensive[d]	5	4	1	10
Like can better or as well	6	2	1	9
Harder to use	0	3	0	3
Too small an opening	0	1	4	5
Stand too high	0	6	0	6
Polyethylene containers are better[d]	0	4	6	10
Too much bother	0	0	3	3
Total Negative Comments	14	24	19	57

[a] Mobil Flamegard (2.5 mil) polyethylene bag.
[b] Figures in parentheses give number of questionnaires returned.
[c] Paper bag.
[d] Plastic containers are supplied free to people who live in Briarwood.

TABLE 52

QUESTIONNAIRE 5 (FOLLOW-UP QUESTIONNAIRE)

	Mobil[a] & Holder	St. Regis[b] & Holder	International[b] & Holder	Can Liner[c]	Chase Bag[d] With Drawstring
System Comparison					
System used	68	87	34	105	108
Number preferring each system	28	52	11	43	31
System preferred (expressed as percentage of total usage)	41.2	59.8	31.4	41.3	28.7

Summary of Responses	Response (202)[e]		Response (Percent)		
	Yes	No	Yes	No	N.R.[f]
Improvements:					
Noise factor	125	48	61.9	23.8	14.3
Neighborhood appearance	164	19	81.2	9.4	9.4
Spillage	129	42	63.9	20.8	15.3
Difficulties:					
Installing liner in barrel	29	116	14.4	57.4	28.2
Removing liner from barrel	31	112	15.3	55.4	29.3
Do you like the system	162	15	80.2	7.4	12.4

Continued . . .

TABLE 52 (Continued)

QUESTIONNAIRE 5 (FOLLOW-UP QUESTIONNAIRE)

[a] Combined responses for Mobil Keepaway and Flamegard (2.5 mil) polyethylene bags.

[b] Paper bag.

[c] Combined responses for Mobil Luxri (1.5 mil), Friedman Wide (3.0 mil), and Wagner (3.5 mil) polyethylene can liners.

[d] Polyethylene bag used on Mobil holder.

[e] Total number of questionnaires returned

[f] No response.

TABLE 53

SUMMARY OF COMMENTS FROM QUESTIONNAIRE 5
(FOLLOW-UP QUESTIONNAIRE)

	Bag System					
Comments	Mobil[a] & Holder	St. Regis[b] & Holder	International[b] & Holder	Can Liner[c]	Chase Bag[d] With Drawstring	Total
Positive						
Wish to continue system	6	11	1	7	3	28
Neater in home and community	0	11	3	12	1	27
Efficient for City and homeowner	1	9	3	5	0	18
Easy to use	4	6	1	1	1	13
Strong	0	4	0	4	5	13
More sanitary	0	5	0	5	0	10
Liked heavy polyethylene bags	0	0	0	0	3	3
No odor problem	3	2	0	1	0	6
No cans to carry out and back	1	2	1	1	1	6
Decomposes at dump	0	3	0	1	1	5
Holds a lot	0	3	0	1	1	5
No empty cans to publicize absence	0	1	0	1		2
Total Positive Comments	15	57	9	39	16	136
Negative						
Top thin, weak, tearing	2	3	0	25	8	38
No good for yard trimmings	4	10	0	16	4	34
Difficult to use/hard to fill	9	1	0	11	10	31
No more taxes, too expensive	8	9	0	7	7	31
Animals and bugs get to bags	1	6	1	13	8	29
Punctures easily	3	0	1	5	5	14

Continued . . .

TABLE 53 (Continued)

SUMMARY OF COMMENTS FROM QUESTIONNAIRE 5 (FOLLOW-UP QUESTIONNAIRE)

	Bag System					
Comments	Mobil[a] & Holder	St. Regis[b] & Holder	International[b] & Holder	Can Liner[c]	Chase Bag[d] With Drawstring	Total
Negative						
Unsatisfactory	2	3	0	5	2	12
Too small of opening	2	3	0	4	0	9
Prefer cans	1	1	0	4	0	6
Market them only for those who want them	1	3	0	0	1	5
Holder ineffective	5	0	0	N.A.[e]	0	5
Make larger	2	0	0	1	2	5
Make lid stay open	4	0	0	N.A.	0	4
Make bags of heavier polyethylene	0	N.A.	N.A.	0	3	3
Make liners with drawstrings	1	N.A.	N.A.	1	1	3
Odor problems	1	0	0	2	0	3
Paper not good for wet items	N.A.	2	0	N.A.	N.A.	2
Unnecessary	1	0	0	0	0	1
Put wheels on holder	1	0	0	N.A.	0	1
Total Negative Comments	48	41	2	94	51	236

[a] Combined responses for Mobil Keepaway and Flamegard (2.5 mil) polyethylene bags.

[b] Paper bag.

[c] Combined responses for Mobil Luxri (1.5 mil), Friedman Wide (3.0 mil), and Wagner (3.5 mil) polyethylene can liner.

[d] Polyethylene bag used on Mobil holder.

[e] Not applicable.

TABLE 54

DIMENSIONAL PROPERTIES OF BAG SAMPLES TESTED IN LABORATORY

Company Identification	Material	Capacity (gal)	Wall Thickness (mil)
Mobil (Flamegard)	Polyethylene	35	2.5
Mobil (Luxri Liner)	"	45	1.5
Mobil (Keepaway)	"	32	2.5
Bemis	"	32	2.0
Bemis	"	32	4.0
Bemis	"	32	6.0
Rapco	"	25	3.2
Central Bag	"	20	2.0
Friedman (Wide)	"	45	3.0
Friedman (Narrow)	"	32	2.5
Wagner	"	45	3.5
Chase (Drawstring)	"	20	2.5

Company Identification	Material[a]	No. Plys	Basis Wt (lb)[b]	Capacity (gal)
Westvaco	Paper	1	100	30
St. Regis (Handi-sack)	"	2	50	32
Bemis	"	1	60	32
International (Garbax)	"	2	50	35

[a] All bags wet-strength, Kraft paper.

[b] Basis weight of 3,000 sq ft of single-ply paper or a ream of 500 sheets of 24" x 36" size (Ref. ASTM Standards, Part 15, April 1965).

TABLE 55

AVERAGE FAILURE LOADS (LB)

Bag Manufacturer	Tensile			Longitudinal Specimens									
				Cottonseed Oil			Vegetable Oil			Milk	Butter	Water 24 Hr	
	Longitude	Transverse	Unspecified Cut	24 Hr	48 Hr	72 Hr	24 Hr	48 Hr	72 Hr	24 Hr	24 Hr	Wet	Dry
Paper													
St. Regis[a] (1/50)	34.30	21.74	N.A.	32.00	33.40	33.80	37.20	32.70	38.40	6.60	30.86	7.26	36.60
St. Regis[b] (1/50)	41.00	34.54	N.A.	33.34	39.20	35.00	32.06	35.40	40.60	8.26	33.60	8.06	34.00
International (2/50)[c]	68.52	42.40	N.A.	57.88	49.20	66.00	61.30	65.20	62.80	15.70	55.60	16.28	58.00
Polyethylene[d]													
Bemis (2 mil)	N.A.	N.A.	2.50	2.50	2.50	2.25	2.25	2.25	2.25	3.00	3.75	2.50	2.50
Bemis (4 mil)	N.A.	N.A.	4.50	3.75	3.75	4.50	3.75	4.50	3.75	4.50	4.75	3.50	4.25
Bemis (6 mil)	N.A.	N.A.	7.00	5.75	5.75	6.50	5.75	7.00	7.00	7.25	7.25	5.75	7.00
Rapco (3.2 mil)	N.A.	N.A.	3.00	3.50	3.25	3.50	3.25	3.25	3.00	3.50	3.25	3.00	3.00
Central Bag (2 mil)	N.A.	N.A.	2.25	2.25	2.25	2.25	2.25	1.50	N.A.	2.00	1.50	2.25	2.25
Mobil[e] (2.5 mil)	N.A.	N.A.	2.80										
Friedman (W) (3.0 mil)	N.A.	N.A.	3.75					f					
Friedman (N) (2.5 mil)	N.A.	N.A.	2.93										
Wagner (3.5 mil)	N.A.	N.A.	3.53										
Chase (2.5 mil)	N.A.	N.A.	2.10										

Continued . . .

TABLE 55 (Continued)

AVERAGE FAILURE LOADS (LB)

Bag	Temperature Exposure 24 Hr			Perforation (Dia.)		Pin Holes (Dia.)		Puncture (Dia.)	
Manufacturer	110 F	32 F	3/32 in.	1/8 in.	1/4 in.	3/8 in.	1/8 in.	1/4 in.	1/2 in.
Paper									
St. Regis[a] (1/50)	33.54	34.30	27.66	25.20	11.80	34.66	10.00	19.40	31.60
St. Regis[b] (1/50)	41.34	41.94	27.46	21.46	12.06	36.90	11.20	27.80	46.80
International (2/50)[c]	67.08	61.20	31.60	26.52	15.68	62.12	14.20	28.40	48.60
Polyethylene									
Bemis (2 mil)[d]	N.D.	2.75	2.25	2.25	2.25	2.50	1.25	3.00	6.00
Bemis (4 mil)	N.D.	4.50	4.00	3.75	3.75	4.00	1.50	4.00	6.75
Bemis (6 mil)	N.D.	7.00	6.75	6.75	6.25	6.75	3.25	7.00	12.50
Rapco (3.2 mil)	N.D.	3.00	2.75	2.75	2.25	2.75	1.50	3.25	7.50
Central Bag (2 mil)	N.D.	1.75	1.75	1.75	1.75	1.75	1.00	2.00	4.25
Mobil[e] (2.5 mil)	3.10	3.05	1.20	1.20	0.93	1.87	1.32	2.70	6.27
Friedman (W) (3.0 mil)	3.70	3.45	1.65	1.65	1.13	2.32	1.90	3.70	8.80
Friedman (N) (2.5 mil)	3.10	2.80	1.43	1.38	1.05	2.17	1.50	3.20	6.90
Wagner (3.5 mil)	3.01	3.01	1.85	1.53	0.90	1.80	1.82	4.22	9.47
Chase (2.5 mil)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.70	2.92	7.22

Continued . . .

TABLE 55 (Continued)

AVERAGE FAILURE LOADS (LB)

[a] Outside layer.

[b] Inside layer.

[c] $2/50 = \frac{2 = \text{Number of Plys}}{50 = \text{Basis Weight of Ply (lb) per 200 bags}}$

[d] 1 mil = 0.001 in.

[e] Mobil Keepaway and Mobil Flamegard were both 2.5 mil thickness and had identical physical properties.

[f] Because earlier oil, milk, butter, and water tests on the Bemis, Rapco, and Central polyethylene bags indicated little discernible effect, these tests were not run on the Mobil, Friedman, and Wagner polyethylene bag samples.

Note: N.A. = Not applicable.
N.D. = Not determined.

TABLE 56

CREEP TESTS ON POLYETHYLENE BAGS AND LINERS

		Recovery (Percent reduction in strain after removing the load)			
		Controlled Environment[a]		Field Environment	
Sample	Use	Longitudinal	Transverse	Longitudinal	Transverse
Mobil[b] (2.5 mil)	Bag	17.3	14.3	14.3	7.15
Friedman (2.5 mil)	Bag	52.5	50.0	48.0	35.7
Friedman (3.0 mil)	Liner	36.0	23.5	33.5 25.0	14.3 18.2
Wagner (3.5 mil)	Liner	50.0	18.7	26.2 19.1	N.D.[c] N.D.

[a] Specimens were tested in a room maintained at 74 ± 2 F and constant humidity.
[b] Mobil Keepaway and Flamegard 2.5 mil bags had identical properties.
[c] Not determined.

TABLE 57

MOISTURE ABSORPTION[a]

Company	Original Moisture Content	Hours of Exposure 24 hr	 48 hr	 72 hr
West Virginia	10.3	97.0	107.5	125.4
St. Regis	9.1	101.9	124.8	129.5
Bemis	10.8	88.2	143.1	147.1

[a] Percent of original weight (dry basis) of paper bag sample.

TABLE 58

MOISTURE EVAPORATION[a]

	Hours After Sealing Bag			
Company	24 hr	48 hr	72 hr	96 hr
West Virginia (paper)	0.0069	0.0515	0.0852	0.0867
Bemis (paper)	0.0435	0.0907	0.1313	0.1362
Mobil[b] (polyethylene)	0.0004	0.0009	0.0013	0.0014

[a] Grams of water lost per square inch of sample bag surface.
[b] Mobil Keepaway and Flamegard 2.5 mil bag specimens.

TABLE 59

DIMENSIONAL CHARACTERISTICS OF BAGS AND CAN LINERS TESTED IN FIELD

Company	Material	Use	Specification Wall Thickness (mil)	Circumference (in.)	Length (in.)	Volume (cu in.)	Basis Wt[a] (lb)	No. of Plys
St. Regis (Handi-sack)	Paper[b]	Bag	9.0	56.0	28.8	7,174	50	2
International (Garbax)	"	"	9.5	54.5	42.0	8,654	50	2
Mobil (Keepaway)	Polyethylene	"	2.5	53.5	35.5	7,092	N.A.[c]	1
Mobil (Flamegard)	"	"	2.5	53.5	43.0	8,590	N.A.	1
Friedman (Narrow)	"	"	2.5	54.5	36.0	7,785	N.A.	1
Chase (Drawstring)	"	"	2.5	47.5	36.0	4,670	N.A.	1
Mobil (Luxri Liner)	"	Liner	1.5	52.0	43.0	11,264	N.A.	1
Friedman (Wide)	"	"	3.0	70.0	44.1	13,838	N.A.	1
Wagner	"	"	3.5	71.0	44.0	14,045	N.A.	1

[a] Basis weight of 3,000 sq ft of single-ply paper or a ream of 500 sheets of 24" x 36" size (Ref. ASTM Standards, Part 15, April 1965).

[b] All bags wet-strength, extensible Kraft paper.

[c] Not applicable.

TABLE 60

SUMMARY OF MATERIAL AND BAG PROPERTIES

Bag		Use	Volume (cu in.)	Unit Cost[a] (¢/bag)	C* x 10^3 (¢/cu in.)	Specification Thickness[b] (mil)	$\sigma_u{}^c$ (psi)	$\epsilon_u{}^c$	$\frac{\sigma_u\text{(Wet)}}{\sigma_u\text{(Dry)}}$	u^c $\left(\frac{\text{in.-lb}}{\text{cu in.}}\right)$	u^* $\left(\frac{\text{in.-lb}}{\text{sq in.}}\right)$
Paper											
St. Regis	Dry[d]	Bag	7,174	9.603	1.3	9.5	7,150	0.03	0.22	262	2.48
	Wet[e]						1,374	0.04		144	1.46
International	Dry[d]	Bag	8,654	9.215	1.1	9.0	5,750	0.085	0.26	234	2.11
	Wet[e]						1,473	N.D.[f]		N.D.	N.D.
Polyethylene											
Mobil (Keepaway)		Bag	7,092	6.95	0.98	2.5	2,100	4.0	1.0	6,000	15.0
Friedman (Narrow)		Bag	7,785	7.049	0.91	2.5	2,344	2.5	1.0	4,700	11.8
Chase (Drawstring)		Bag	4,670	8.736	1.87	2.5	2,175	5.3	1.0	7,573	18.9
Mobil (Luxri Liner)		Liner	11,264	5.5	0.49	1.5	2,000[g]	4.5[g]	1.0	7,264[g]	10.9[g]
Friedman (Wide)		Liner	13,838	13.68	0.99	3.0	2,500	6.0	1.0	7,300	21.9
Wagner		Liner	13,838	13.00	0.94	3.5	2,100	4.5	1.0	6,250	21.9

[a] Data is based on cost of bags purchased for present field study.

[b] This is the manufacturer's specification thickness and not the measured thickness of the actual test specimen.

[c] Based on tensile test data, reference Figure 39, 40, and 41.

[d] Average volumes compiled from transverse and longitudinal tests conducted on inner and outer bag layers.

[e] Wet samples (24 hour).

[f] Not determined.

[g] Average values from opposite sides of the bag. Differences of the order of 50 percent were recorded.

TABLE 61

HOUSEHOLDERS' RATINGS (a_i) FOR TOTAL EVALUATION OF BAG SUITABILITY

		Ratings[a] (a_i)				
Factors	Questionnaire Number	Mobil[b] & Holder	St. Regis[c] & Holder	International[c] & Holder	Can Liner[d]	St. Regis[c] No Holder
1. Frequency of Bag Failure	2	5.13	10.0	9.40	9.82	8.87
	3	7.44	10.0	8.97	9.99	
	4	10.0	9.65	9.94		
2. Ease of Closure of Filled Bag	2	9.44	9.62	9.87	10.0	4.94
	3	7.94	9.97	8.07	10.0	
	4	10.0	9.95	8.71		
3. Ease of Mounting Bag or Liner	2	7.52	9.38	10.0	9.70	5.27
	3	7.03	10.0	10.0	9.70	
	4	10.0	9.14	9.65		
4. Ease of Filling Bag	2	6.50	9.55	9.16	10.0	7.78
	3	5.03	10.0	8.76	9.43	
	4	10.0	9.88	9.05		
5. Odor Control	2	8.75	9.72	8.27	10.0	8.75
	3	8.50	10.0	9.04	8.96	
	4	10.0	9.07	7.59		
6. Frequency of Spillage	2	7.89	8.34	7.21	10.0	6.79
	3	8.65	10.0	9.05	9.47	
	4	10.0	8.70	6.80		
7. Frequency and Extent of Animal Damage	2	6.95	2.70	4.77	10.0	4.89
	3	8.12	8.78	8.12	10.0	
	4	10.0	8.24	10.0		

Continued . . .

TABLE 61 (Continued)

HOUSEHOLDERS' RATINGS (a_i) FOR TOTAL EVALUATION OF BAG SUITABILITY

[a] Ratings are derived from responses to Questionnaires 2, 3, and 4 which are given in Tables H2, H4, and 50, respectively.

[b] Ratings for Questionnaires 2 and 3 refer to the Mobil Keepaway (2.5 mil) polyethylene bag. Ratings for Questionnaire 4 refer to the Mobil Flamegard (2.5 mil) polyethylene bag.

[c] Paper bag.

[d] Ratings for Questionnaire 2 refer to the Friedman Wide (3.0 mil) polyethylene can liner Ratings for Questionnaire 3 refer to the Wagner (3.5 mil) polyethylene can liner.

TABLE 62

QUESTIONNAIRE 5, IMPORTANCE RATINGS
(Number of Responses)

Item	Importance			
	None	Very Little	Moderate	Great
Frequency of Bag Failure	0	4	14	14
Ease of Closure of Filled Bag	1	6	14	11
Ease of Mounting Bag or Liner	2	7	9	10
Ease of Filling Bag	1	3	12	15
Ease of Operations of Holder Lid[a]	2	3	13	12
Odor Conditions	2	0	9	19
Ease of Storage of Bag Supply[b]	7	8	8	9
Ease of Carrying Filled Bag[b]	4	6	14	6
Frequency of Spillage	0	8	11	14
Frequency and Extent of Animal Damage	2	4	9	14

[a] Item was not used in subsequent algorithm ratings ($a_i b_i$) because it pertained only to bags on holders.

[b] Item was not used in subsequent algorithm ratings ($a_i b_i$) due to insufficient data from questionnaires 2 and 4.

TABLE 63

QUESTIONNAIRE 5, IMPORTANCE RATINGS
(Expressed as Percentages of Total Response)

	Importance			
Item	None	Very Little	Moderate	Great
Frequency of Bag Failure	0	12.4	43.8	43.8
Ease of Closure of Filled Bag	3.1	18.8	43.8	34.3
Ease of Mounting Bag or Liner	7.1	25.0	32.1	35.8
Ease of Filling Bag	3.2	9.7	38.7	48.4
Ease of Operations of Holder Lid[a]	6.7	10.0	43.3	40.0
Odor Conditions	6.7	0	30.0	63.3
Ease of Storage of Bag Supply[b]	21.9	25.0	25.0	28.1
Ease of Carrying Filled Bag[b]	13.3	20.0	46.7	20.0
Frequency of Spillage	0	24.2	33.3	42.5
Frequency and Extent of Animal Damage	6.9	13.8	31.1	48.2

[a] Item was not used in subsequent algorithm ratings ($a_i b_i$) because it pertained only to bags on holders.

[b] Item was not used in subsequent algorithm ratings ($a_i b_i$) due to insufficient data from questionnaires 2 and 4.

TABLE 64

WEIGHTING COEFFICIENTS (b_i) FOR TOTAL EVALUATION OF BAG SUITABILITY

Item	None[a]	Very Little[b]	Moderate[c]	Great[d]	Total Units	Weighting Coefficient (b_i)
1. Frequency of Bag Failure	0	12.4	87.6	131.4	231.4	0.149
2. Ease of Closure of Filled Bag	0	18.8	87.6	102.9	209.3	0.134
3. Ease of Mounting Bag or Liner	0	25.0	64.2	107.4	196.6	0.126
4. Ease of Filling Bag	0	9.7	77.4	145.2	232.3	0.149
5. Odor Control	0	0	60.0	189.9	249.9	0.160
6. Frequency of Spillage	0	24.2	66.6	127.5	218.3	0.140
7. Frequency and Extent of Animal Damage	0	13.8	62.2	144.6	220.6	0.142
Σ	0	103.9	505.6	948.9	1,558.4	1.000

[a] Assign zero units.
[b] Assign one unit.
[c] Assign two units.
[d] Assign three units.

TABLE 65

ALGORITHM RATINGS ($a_i b_i$)
FOR TOTAL EVALUATION OF BAG SUITABILITY

Factors	Questionnaire Number	Weighted Ratings ($a_i b_i$)				
		Mobil[a] & Holder	St. Regis[b] & Holder	International[b] & Holder	Can Liner[c]	St. Regis[b] No Holder
1. Frequency of Bag Failure	2	0.764	1.490	1.401	1.463	1.322
	3	1.109	1.490	1.337	1.489	
	4	1.490	1.438	1.481		
2. Ease of Closure of Filled Bag	2	1.265	1.289	1.323	1.340	0.662
	3	1.064	1.336	1.081	1.340	
	4	1.340	1.333	1.167		
3. Ease of Mounting Bag or Liner	2	0.948	1.182	1.260	1.222	0.664
	3	0.886	1.260	1.260	1.222	
	4	1.260	1.152	1.216		
4. Ease of Filling Bag	2	0.969	1.423	1.365	1.490	1.159
	3	0.749	1.490	1.305	1.405	
	4	1.490	1.472	1.348		
5. Odor Control	2	1.400	1.555	1.323	1.600	1.400
	3	1.360	1.600	1.446	1.434	
	4	1.600	1.451	1.214	1.434	
6. Frequency of Spillage	2	1.105	1.168	1.009	1.400	0.951
	3	1.211	1.400	1.267	1.326	
	4	1.400	1.218	0.952		
7. Frequency and Extent of Animal Damage	2	0.987	0.383	0.677	1.420	0.694
	3	1.153	1.247	1.153	1.420	
	4	1.420	1.170	1.420		

Continued . . .

TABLE 65 (Continued)

ALGORITHM RATINGS (a_ib_i) FOR TOTAL EVALUATION OF BAGS SUITABILITY

		Weighted Ratings (a_ib_i)				
Factors	Questionnaire Number	Mobil[a] & Holder	St. Regis[b] & Holder	International & Holder	Can Liner[c]	St. Regis[b] No. Holder
Total Bag Ratings						
7	2	7.438	8.490	8.358	9.935	6.852
a_ib_i	3	7.532	9.823	8.849	9.636	
$i = 1$	4	10.000	9.234	8.748		
Average Rating	2,3,4	(7.485)[d] 10.000	9.182	8.652	9.786	6.852

[a] Ratings for Questionnaires 2 and 3 refer to Mobil Keepaway (2.5 mil) polyethylene bag. Ratings for Questionnaire 4 refer to Mobil Flamegard (2.5 mil) polyethylene bag.

[b] Paper bag.

[c] Ratings for Questionnaire 2 refer to the Friedman Wide (3.0 mil) polyethylene can liner. Ratings for Questionnaire 3 refer to the Wagner (3.5 mil) polyethylene can liner.

[d] Average for Mobil and Holder on all three questionnaires is not valid due to the change in holder model and its effect on the system rating as reflected in responses to Questionnaire 4 when compared to Questionnaires 2 and 3.

TABLE 66

COLLECTION TIMES

Designated Crew Size (CS)	Time, t, in Minutes per Stop[a]	
	Cans	Bags
One[b]	0.74	0.58
Two[c]	0.69	0.53
Three[c]	0.58	0.41

[a] Minutes per stop includes travel time to the next stop. Data was taken during the demonstration study for one-man crews. Simulations of two- and three-man crews were based on MTM analyses.

[b] Actual times recorded during collection in Inglewood.

[c] Derived by Methods-Time-Measurement (MTM) analysis. Times for standard work-task elements of a collector during waste collection were determined for each task from field data and used to construct the work-task collection times for 2 and 3 men. Travel time is constant for all crew sizes.

TABLE 67

COSTS OF VEHICLE TIME - EQUIPMENT COST ONLY[a]

Truck Size[b]	12 cu yd	16 cu yd	20 cu yd	25 cu yd	32 cu yd	40 cu yd
Collection Time	$3.75/hr 6.25¢/min	$3.90/hr 6.50¢/min	$4.12/hr 6.85¢/min	$4.20/hr 7.00¢/min	$4.73/hr 7.90¢/min	$5.10/hr 8.50¢/min
Haul Time	$4.00/hr 6.67¢/min	$4.35/hr 7.25¢/min	$4.60/hr 7.67¢/min	$5.10/hr 8.50¢/min	$5.74/hr 9.57¢/min	$6.20/hr 10.33¢/min
Relief Time	$2.00/hr 3.33¢/min	$2.18/hr 3.63¢/min	$2.30/hr 3.83¢/min	$2.55/hr 4.25¢/min	$2.87/hr 4.78¢/min	$3.10/hr 5.17¢/min

[a] Based on operating costs of the City of Inglewood, and equipment depreciation and maintenance costs calculated from manufacturers' figures. Labor rates ($4.80 per hour) are given on page 59.

[b] Waste load volume.

TABLE 68

UNIT COSTS OF CAN AND BAG SYSTEMS[a]

Container System	Wholesale Price Schedule[b]				Retail Price Schedule[c]				Collection Cost[d] $/container/service	
	$/ container	$/ container service	$/holder	$/holder service	$/ container	$/ container service	$/holder	$/holder service	25 cu yd truck	35 cu yd truck
Cans:										
Metal	N.A.[f]	N.A.	N.A.	N.A.	4.79	0.12[g]	N.A.	N.A.	0.098	0.0915
Plastic, L.D.[e]	N.A.	N.A.	N.A.	N.A.	5.99	0.15	N.A.	N.A.	0.098	0.0915
Plastic, H.D.	N.A.	N.A.	N.A.	N.A.	9.49	0.237	N.A.	N.A.	0.098	0.0915
Liner:										
Polyethylene (Mobil Luxri)	0.055	0.055	6.23	0.024[h]	0.0799	0.0799	6.23	0.024	0.0629	0.0684
Bags:										
Paper (St. Regis)	0.09603	0.09603	12.00	0.0231[i]	0.09603	0.09603	12.00	0.0231	0.0629	0.0684
Polyethylene (Mobil Keepaway)	0.0695	0.0695	8.90	0.0171	0.117	0.117	5.79	0.0112	0.0629	0.0684
Bin Liner:										
Polethylene (Bemis 3 cu yd)	0.4294	0.4294	190.00[j]	0.0369	0.85	0.85	190.00	0.0369	0.0629	0.0684

Continued . . .

TABLE 68 (Continued)

UNIT COSTS OF CAN AND BAG SYSTEMS[a]

[a] All costs are based on 32 gal container capacities. Tax is not included. rvice weekly, 52 times per year.

[b] Wholesale prices are lot sizes greater than 1,000, based on demonstration project costs, 1969-1970 (Table 11).

[c] Retail prices are based on August 1970 store prices.

[d] Collection costs are from Figure 53, based on field survey motion-time studies; 411 bag services per day, 325 can services per day.

[e] L.D. = light duty; H.D. = heavy duty.

[f] Not applicable.

[g] Costs based on 2 year can life; 2.6 cans/unit/service; as follows:

$$\frac{2.6 \times \$/\text{container}}{2\ \text{yr} \times 52\ \text{services/yr}} = \$/\text{container/service}.$$

[h] Based on 5 year can life using one can as a holder.

[i] Based on 10 year holder life.

[j] Bin prices based on Dempster 3 cu yd bin, 10 year life without liner, 15 year life with liner, 6.6 services per week.

TABLE 69

COST ANALYSIS - CAN AND BAG SYSTEMS - CITY (WHOLESALE) DISTRIBUTION SYSTEM
($/residence/year)

	25 CU YD TRUCKS					35 CU YD TRUCKS		
Container System	Container	Holder	Container Distribution[a]	Collection[b]	Total	Container, Holder and Distribution Costs	Collection[b]	Total
Cans:								
Metal	N.A.[c]	N.A.	N.A.	13.26	13.26	N.A.	12.38	12.38
Plastic, L.D.	N.A.	N.A.	N.A.	13.26	13.26	N.A.	12.38	12.38
Plastic, H.D.	N.A.	N.A.	N.A.	13.26	13.26	N.A.	12.38	12.38
Liner:								
Polyethylene[d]								
in can[e]	7.43	1.25[f]	4.34	8.50	21.52	13.02	9.25	22.27
on holder[g]	8.86	0.89	4.34	10.14	24.23	14.09	11.02	25.11
Bags:								
Paper[h]	15.48[i]	1.20	4.34	10.14	31.16	21.02[i]	11.02	32.04
Polyethylene[i]	11.20	0.89	4.34	10.14	26.57	16.43	11.02	27.45

Continued . . .

TABLE 69 (Continued)

COST ANALYSIS - CAN AND BAG SYSTEMS - CITY (WHOLESALE) DISTRIBUTION SYSTEM

[a] Container distribution costs are the direct labor and equipment costs incurred in distributing the bags to residences during the study.

[b] Collection costs taken from Figure 53.

[c] Not applicable.

[d] Mobil Luxri 1.5 mil liner.

[e] Liners in can costs are based on 2.6 liners per week equivalent to 2.6 cans per week. Assumes liners in cans are filled as much as cans alone.

[f] Holder is one can depreciated over 5 years.

[g] Liners on holders. Liners sold in retail stores are for use in cans or hung from holders based on 3.1 liners per week. Assumes liners are filled as much as bags.

[h] St. Regis bag; costs are based on 3.1 bags per week.

[i] Paper bags are not presently distributed through retail stores but are available to individuals at the quoted wholesale price from the manufacturer.

[j] Mobil Keepaway 2.5 mil bag; costs are based on 3.1 bags per week.

TABLE 70

COST ANALYSIS - CAN AND BAG SYSTEMS - PRIVATE (RETAIL) PURCHASE SYSTEM

($/residence/year)

Container System	25 CU YD TRUCKS				35 CU YD TRUCKS		
	Container	Holder	Collection[a]	Total	Container and Holder Costs	Collection[a]	Total
Cans:							
Metal	6.23	0	13.26	19.49	6.23	12.38	18.61
Plastic, L.D.[b]	7.80	0	13.26	21.06	7.80	12.38	20.18
Plastic, H.D.	12.32	0	13.26	25.58	12.32	12.38	24.70
Liner:							
Polyethylene[c]							
in can[d]	10.79	1.25	8.50	20.54	12.04	9.25	21.29
on holder[e]	12.86	0.59	10.14	23.59	13.45	11.02	24.47
Bags:							
Paper[f]	15.48[g]	1.20	10.14	26.82	16.68[g]	11.02	27.70
Polyethylene	18.86	0.59	10.14	29.59	19.45	11.02	30.47

Continued . . .

TABLE 70 (Continued)

COST ANALYSIS - CAN AND BAG SYSTEMS - PRIVATE (RETAIL) PURCHASE SYSTEM
($/residence/year)

[a] Collection costs taken from Figure 53.

[b] L.D. = light duty; H.D. = heavy duty.

[c] Mobil Luxri 1.5 mil liner.

[d] Liners in can costs are based on 2.6 liners per week equivalent to 2.6 cans per week. Assumes liners in cans are filled as much as cans alone.

[e] Liners on holders. Liners sold in retail stores are for use in cans or hung from holders based on 3.1 liners per week. Assumes liners are filled as much as bags.

[f] St. Regis bag; costs are based on 3.1 bags per week.

[g] Paper bags are not presently distributed through retail stores but are available to individuals at the quoted wholesale price from the manufacturer.

TABLE 71

BENEFIT-COST EVALUATION FOR HOUSEHOLDERS[a]

($/residence/year)

Container System	Wholesale Costs	Retail Costs	Benefit Incentive[b]	Net Cost Less Benefit	
				Wholesale	Retail
Cans:					
Metal	N.A.[c]	18.74	0	N.A.	18.74
Plastic, L.D.[d]	N.A.	20.29	0	N.A.	20.29
Plastic, H.D.[d]	N.A.	24.79	0	N.A.	24.79
Liner, Polyethylene:					
in can	22.15	21.18	6.76	15.39	14.42
on holder	24.98	24.33	6.76	18.22	17.57
Bags:					
Paper	31.90	27.55	6.76	25.14	20.79
Polyethylene	27.32	30.38	6.76	20.56	23.62

[a] Data is the weighted average for 18-35 cu yd trucks and 3-25 cu yd trucks from Tables 69 and 70.

[b] Benefits are determined from savings in washing calculated as follows: Labor = 3 min per can at $1.50 per hr or $.025 per min = $.075; detergent and water = $.055; total cost per can = $0.13/washing; 2 cans washed every 2 weeks.

[c] Not applicable.

[d] L.D. - light duty; H.D. - heavy duty.

TABLE 72

EFFECTS OF BAGS ON COLLECTION VEHICLE WASTE DENSITIES

	Trips per Route Week No.					Solid Waste Vehicle Load (tons per 25 cu yd vehicle)			
Route	1	2	3	4	5				
1 (bag)	1	1	-[a]	1	1[b]+	10.5	10.6	10.7	10.7[c]
2 (can)	1	1	-	-	1	8.8	9.7	9.5	9.7
3 (can)	-	1	1+	1+	1+	10.9	9.3[c]	11.0[c]	10.7[c]
4 (bag)	-	1	1	1+	1	10.2	10.2	11.3[c]	10.5
5 (bag)	1	1+	-	1+	-	10.4	9.7[c]	9.9[c]	-
6 (can)	1+	1+	-	1+	-	9.2[c]	8.5[c]	8.5[c]	-

Packer Density (lb/cu yd)[c]

Bag Routes	1	4	5	Mean Density
	856	907	772 788	831
Can Routes	2	3	6	
	(no fully loaded vehicles were observed)	741 878 856	737 680 681	762

a No observation.
b Vehicle returned to the route from the landfill and collected a partial load.
c Denotes fully loaded vehicles, others completed collection with less than a full load.

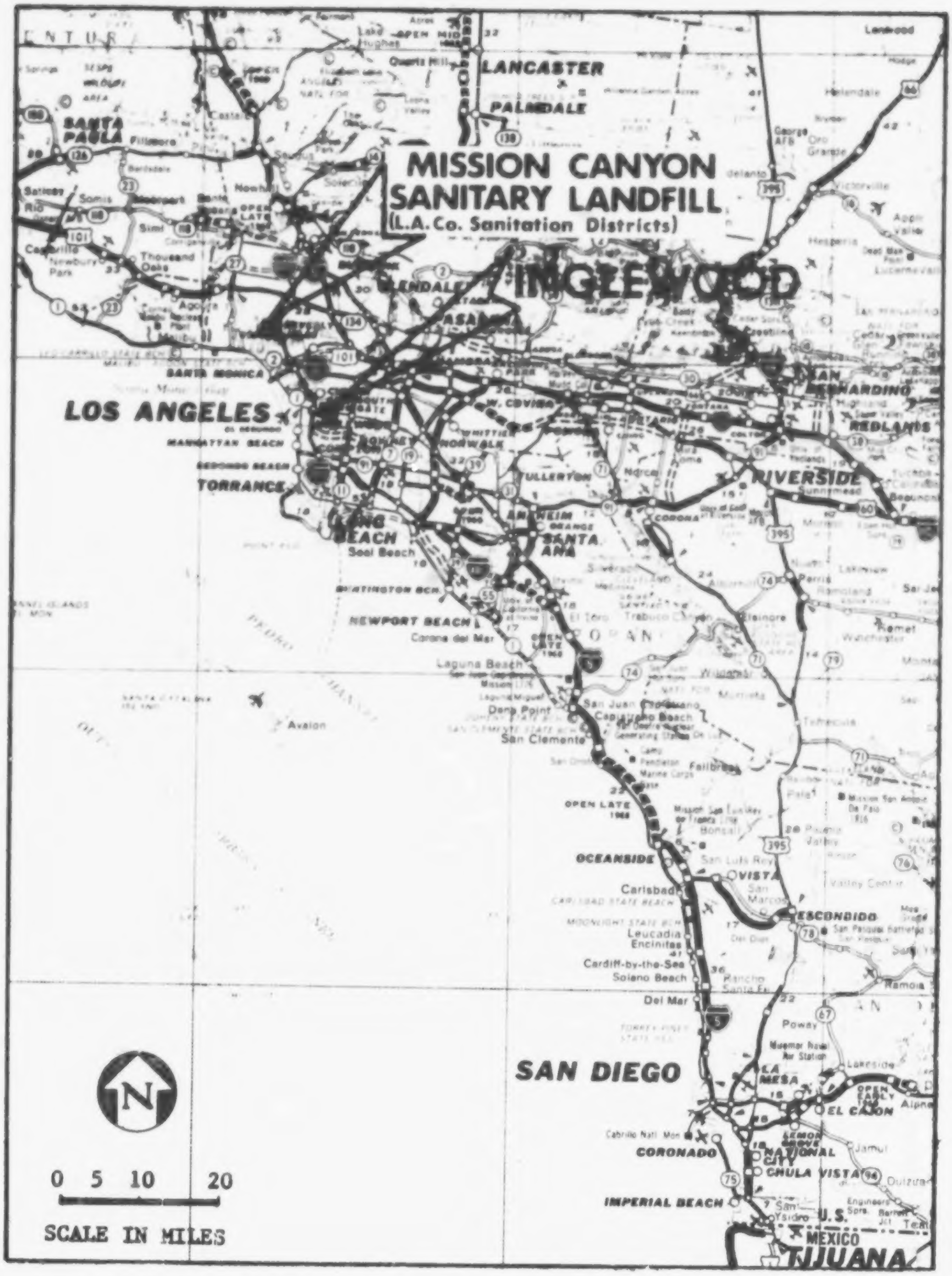
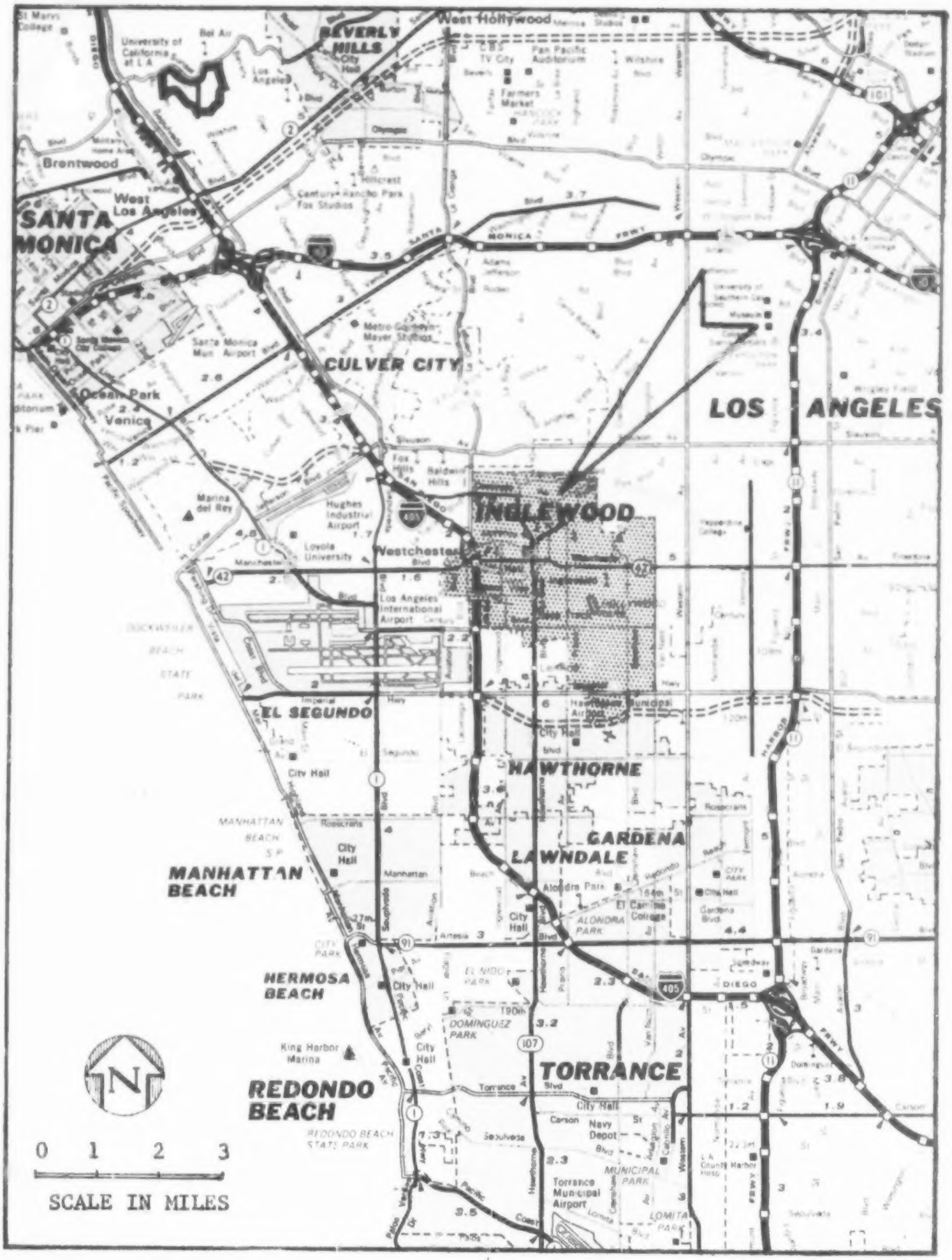

MISSION CANYON
SANITARY LANDFILL
(L.A. Co. Sanitation Districts)
INGLEWOOD
LANCASTER
PALMDALE
SANTA PAULA
LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
REDONDO BEACH
TORRANCE
LONG BEACH
NORWALK
WHITTIER
FULLERTON
ANAHEIM
SANTA ANA
SAN BERNARDINO
REDLANDS
RIVERSIDE
CORONA
NEWPORT BEACH
Laguna Beach
San Clemente
OCEANSIDE
Carlsbad
ESCONDIDO
Del Mar
SAN DIEGO
LA MESA
EL CAJON
CORONADO
NATIONAL CITY
CHULA VISTA
IMPERIAL BEACH
MEXICO
TIJUANA
Avalon
N
0 5 10 20
SCALE IN MILES

FIGURE 1

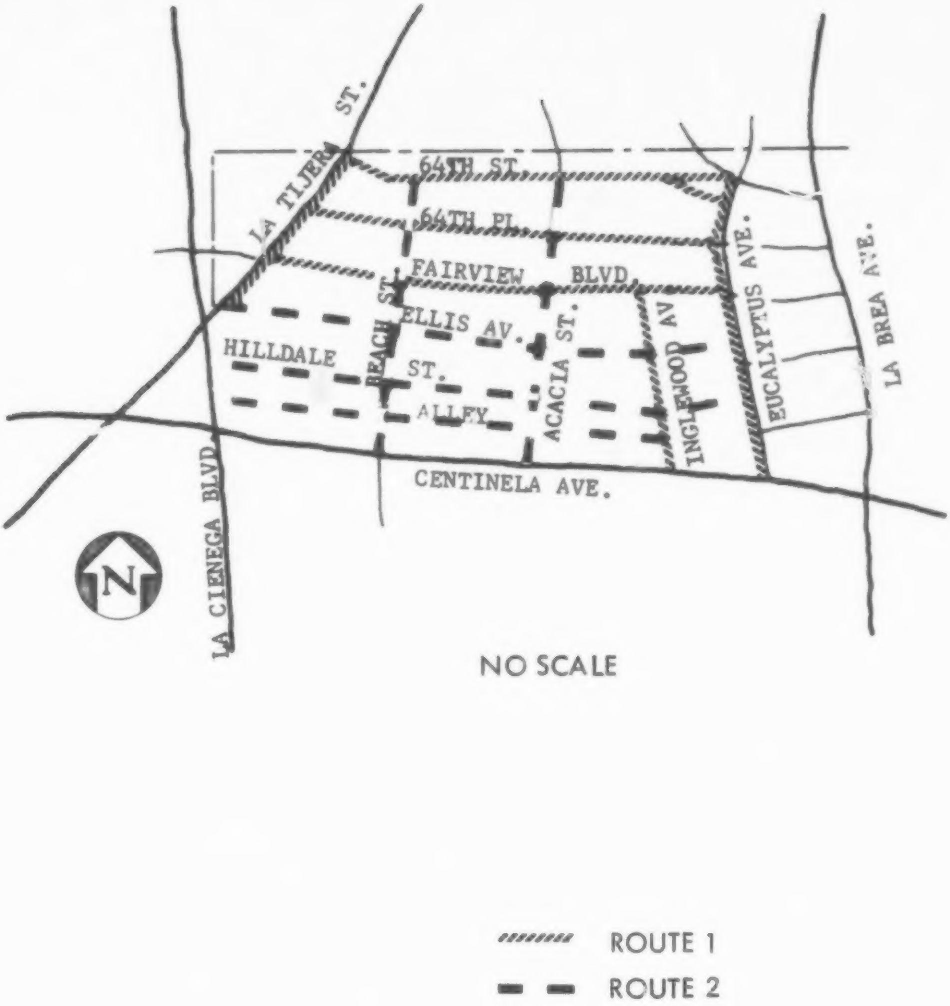
LOCATION MAP
SOUTHERN CALIFORNIA

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


BEVERLY HILLS
West Hollywood
SANTA MONICA
Brentwood
West Los Angeles
CULVER CITY
Ocean Park
Venice
Marina del Rey
LOS ANGELES
INGLEWOOD
Westchester
Los Angeles International Airport
EL SEGUNDO
HAWTHORNE
GARDENA
LAWNDALE
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
TORRANCE
N
0 1 2 3
SCALE IN MILES

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 2
LOCATION MAP
LOS ANGELES AREA



LA TIJERA ST.
64TH ST.
64TH PL.
FAIRVIEW BLVD.
ELLIS AV.
HILLDALE ST.
ALLEY
BEACH ST.
ACACIA ST.
INGLEWOOD AV.
EUCALYPTUS AVE.
LA BREA AVE.
CENTINELA AVE.
LA CIENEGA BLVD.
N
NO SCALE
ROUTE 1
ROUTE 2

FIGURE 3

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

STREET MAP, STUDY AREA A
SINGLE FAMILY RESIDENTIAL AREA

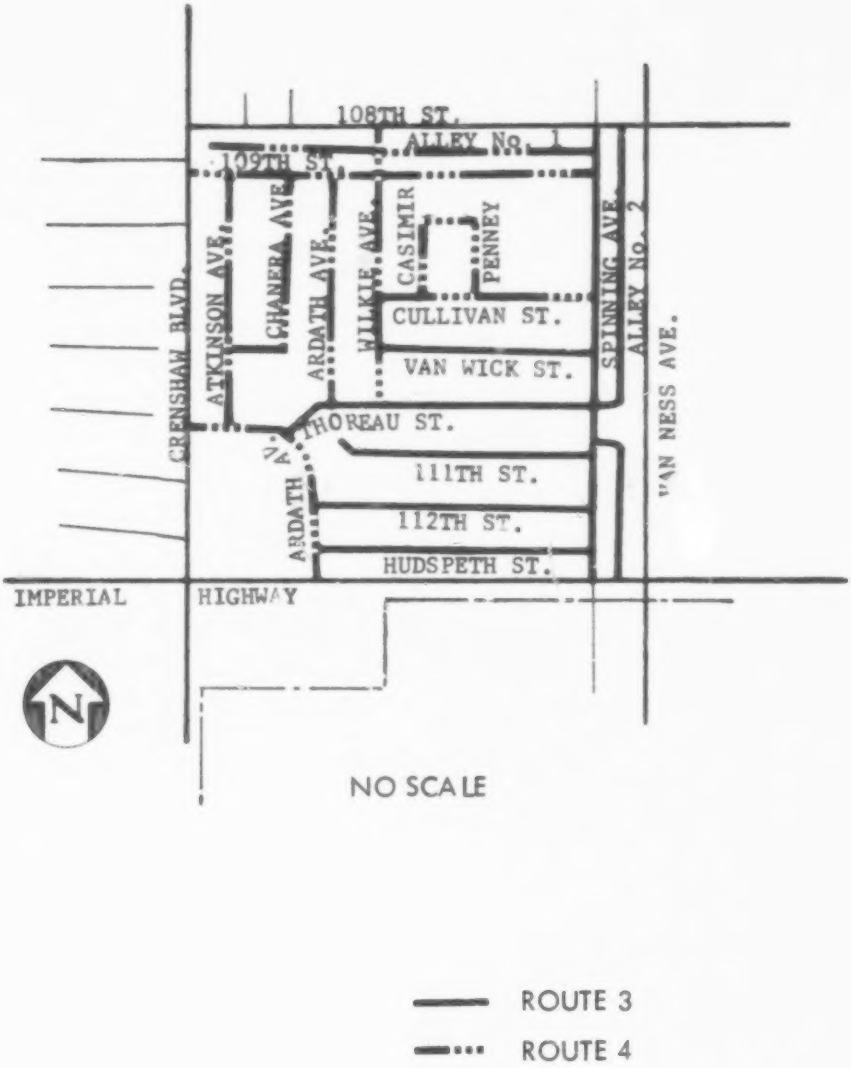

108TH ST.
ALLEY No. 1
109TH ST.
CRENSHAW BLVD.
ATKINSON AVE.
CHANERA AVE.
ARDATH AVE.
WILKIE AVE.
CASIMIR
PENNEY
CULLIVAN ST.
VAN WICK ST.
SPINNING AVE.
ALLEY No. 2
VAN NESS AVE.
THOREAU ST.
ARDATH AV.
111TH ST.
112TH ST.
HUDSPETH ST.
ARDATH
IMPERIAL
HIGHWAY
N
NO SCALE
ROUTE 3
ROUTE 4

FIGURE 4

STREET MAP, STUDY AREA B
SINGLE FAMILY RESIDENTIAL AREA

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

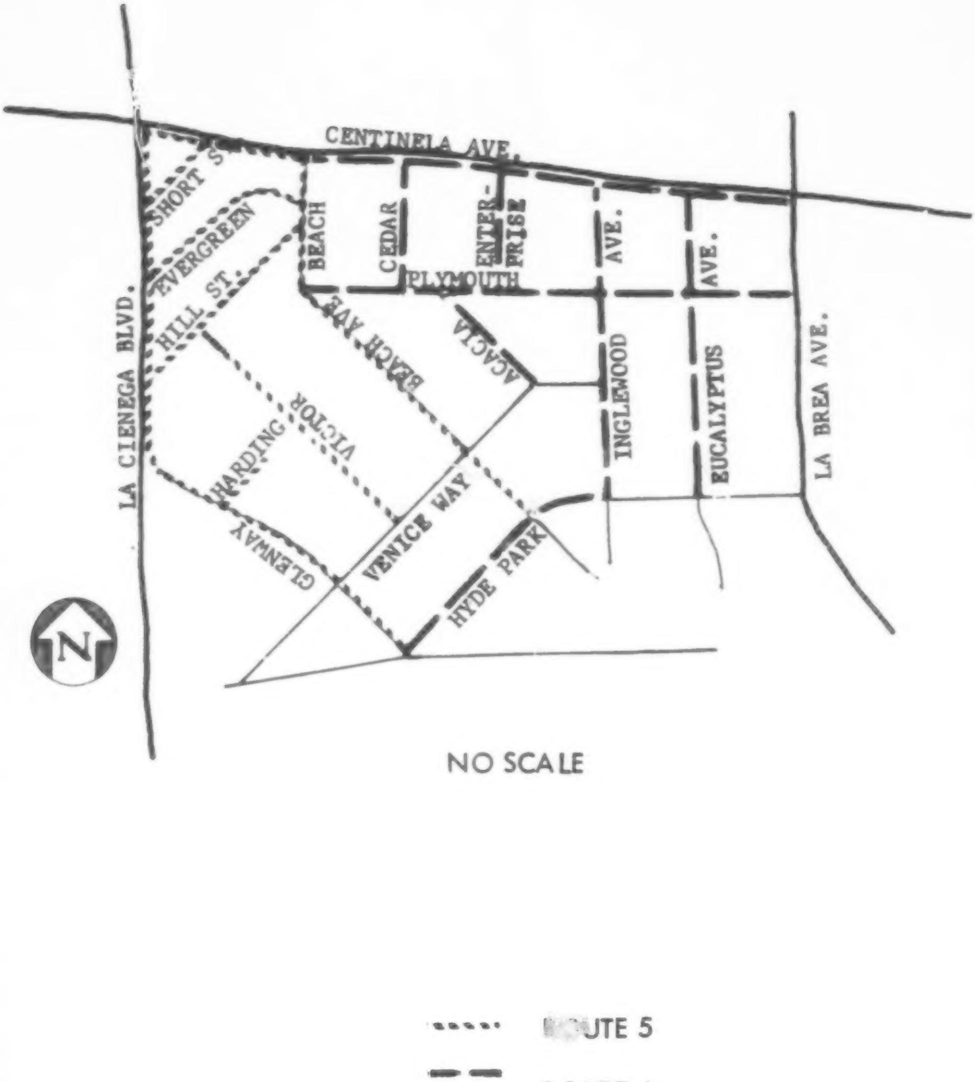
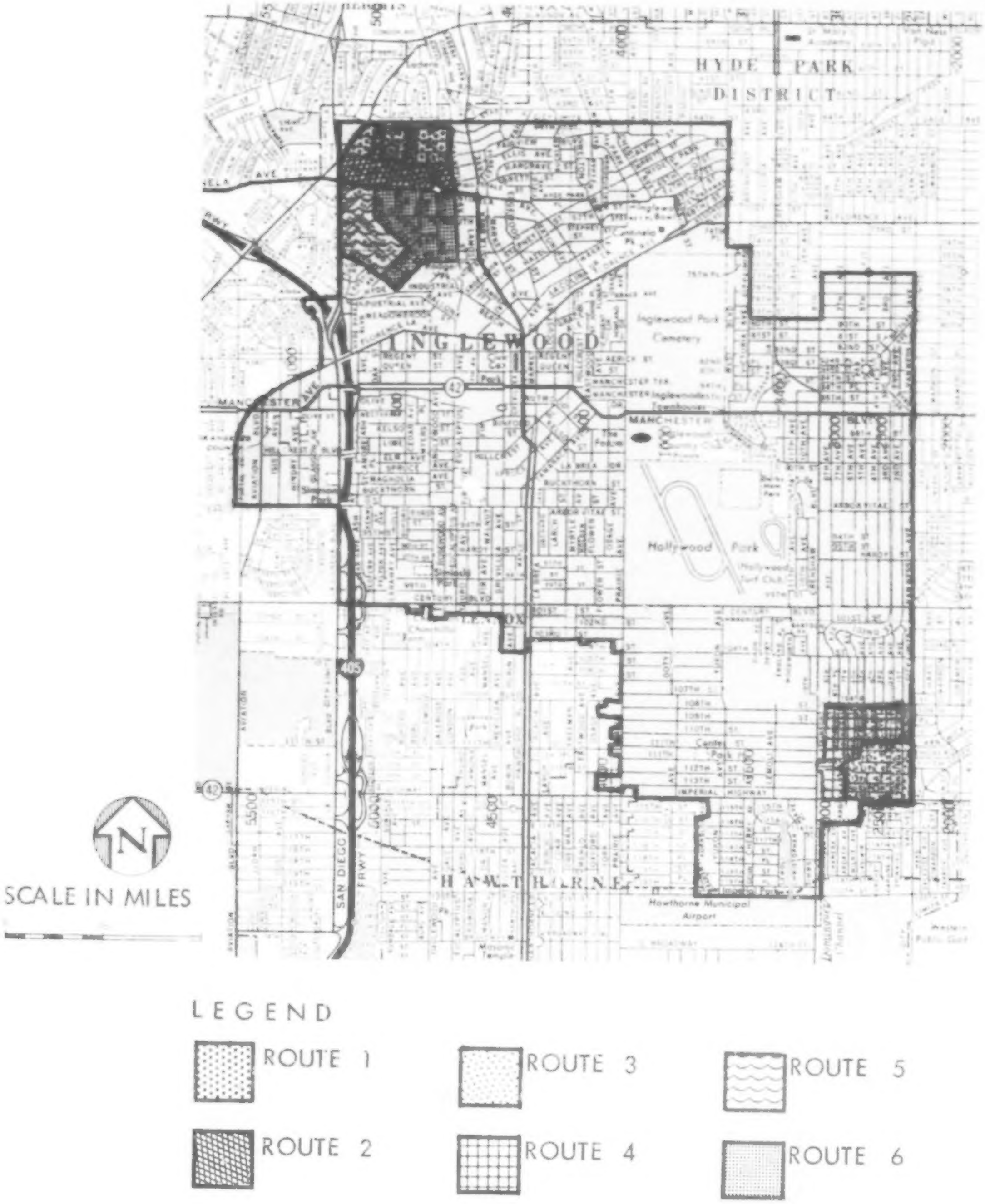

CENTINELA AVE.
SHORT S
EVERGREEN
HILL ST.
BEACH
CEDAR
ENTER-
PRISE
AVE.
AVE.
PLYMOUTH
BEACH AVE
ACACIA
LA CIENEGA BLVD.
VICTOR
HARDING
GLENWAY
VENICE WAY
HYDE PARK
INGLEWOOD
EUCALYPTUS
LA BREA AVE.
N
NO SCALE
ROUTE 5
ROUTE 6

FIGURE 5

STREET MAP, STUDY AREA C
SINGLE AND MULTIPLE
FAMILY RESIDENTIAL AREA

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


HYDE PARK DISTRICT
INGLEWOOD
Inglewood Park Cemetery
MANCHESTER
Hollywood Park
SAN DIEGO FRWY
405
42
HAWTHORNE
Hawthorne Municipal Airport
N
SCALE IN MILES
LEGEND
ROUTE 1
ROUTE 2
ROUTE 3
ROUTE 4
ROUTE 5
ROUTE 6

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 6

STUDY AREA LOCATIONS
INGLEWOOD, CALIFORNIA

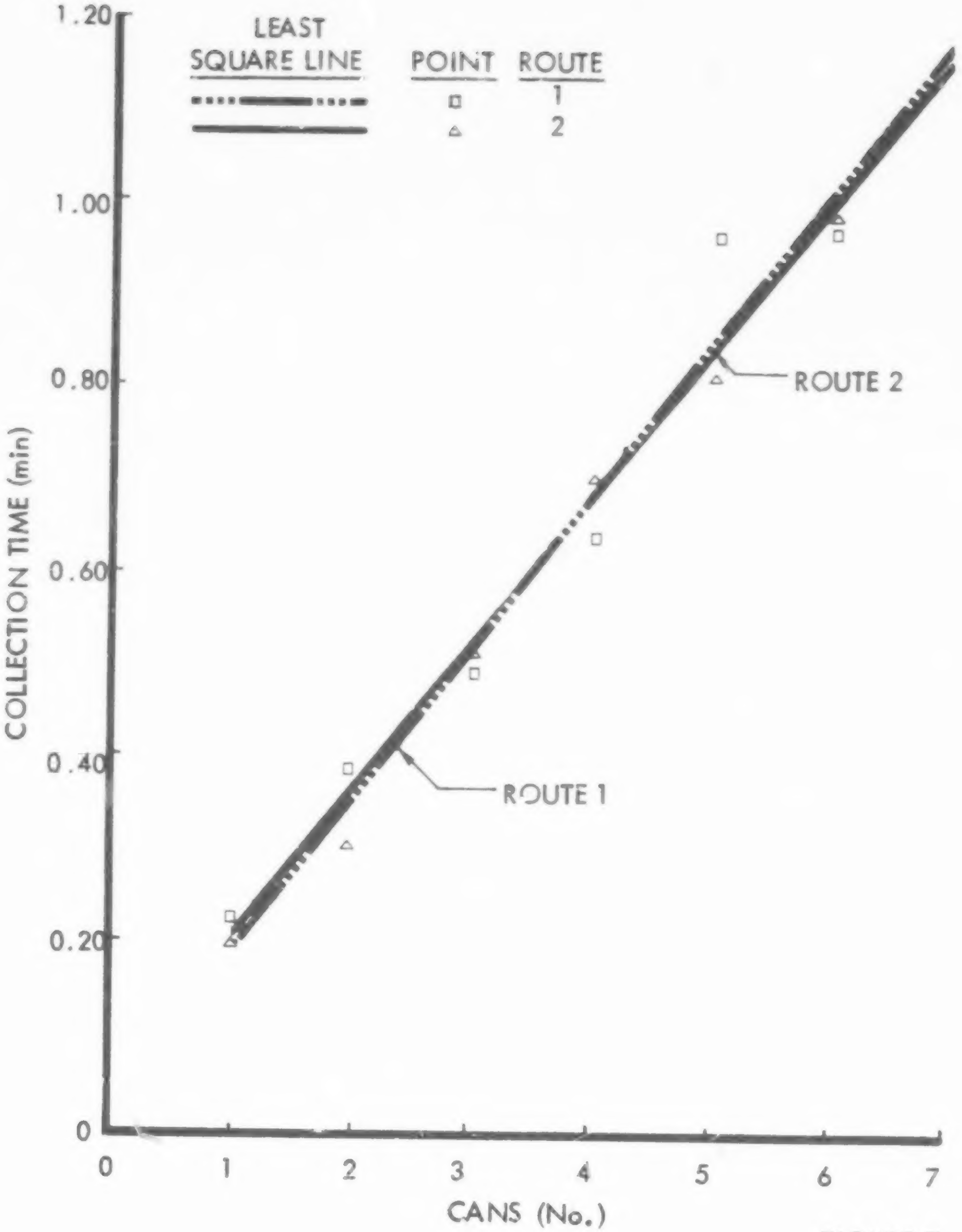


FIGURE 7

COLLECTION TIME
CANS ONLY - AREA A

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

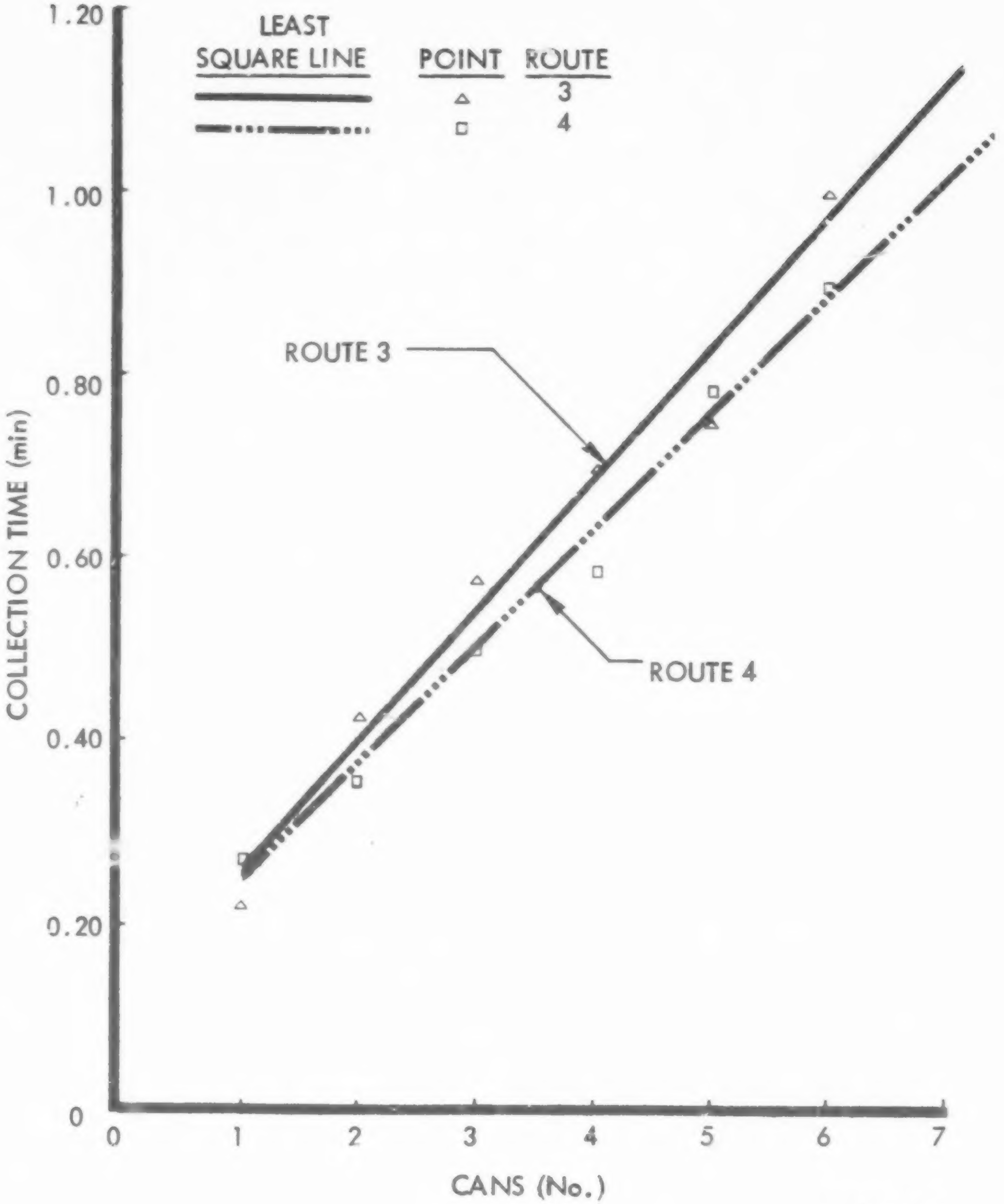


FIGURE 8

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

COLLECTION TIME
CANS ONLY - AREA B

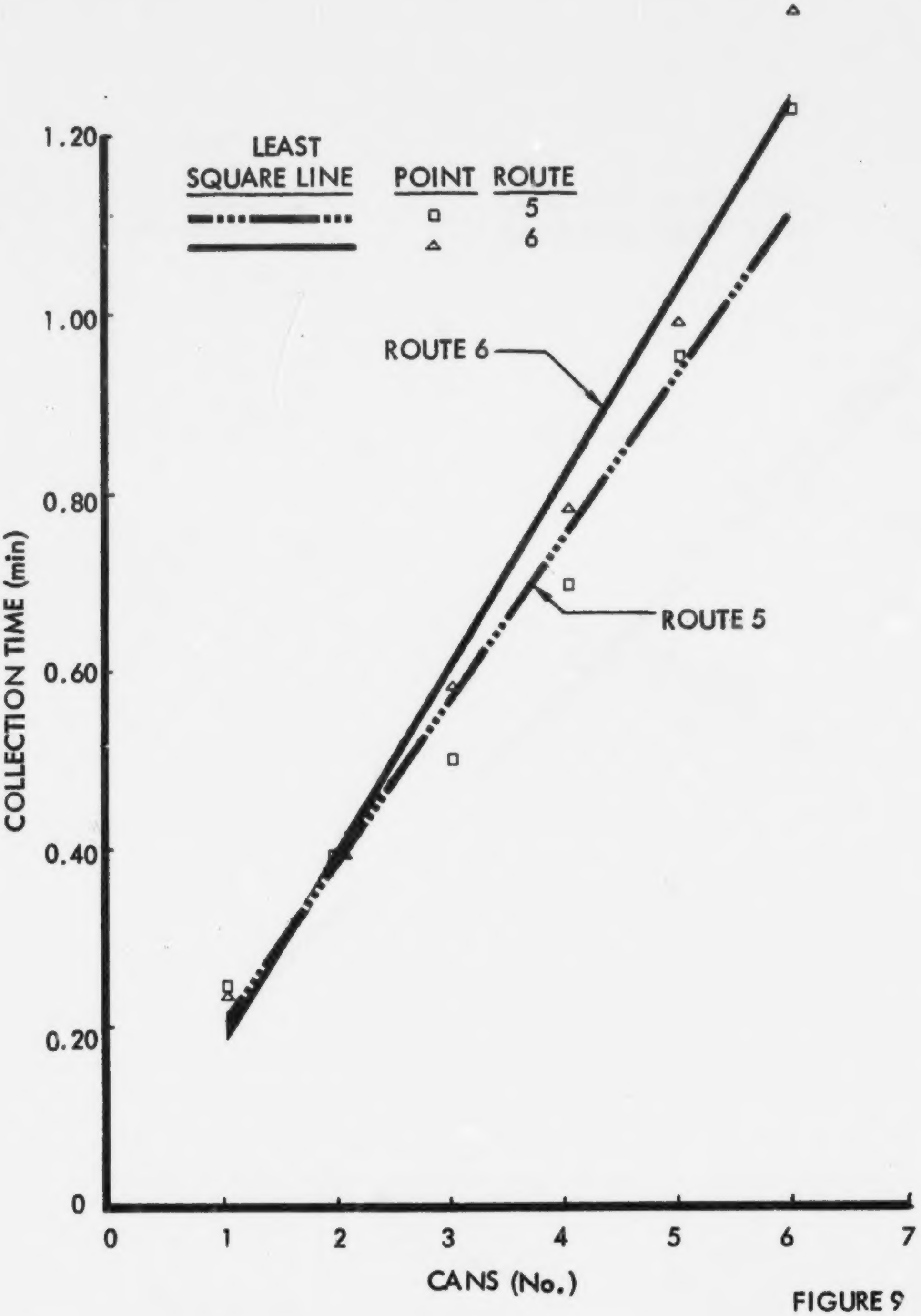
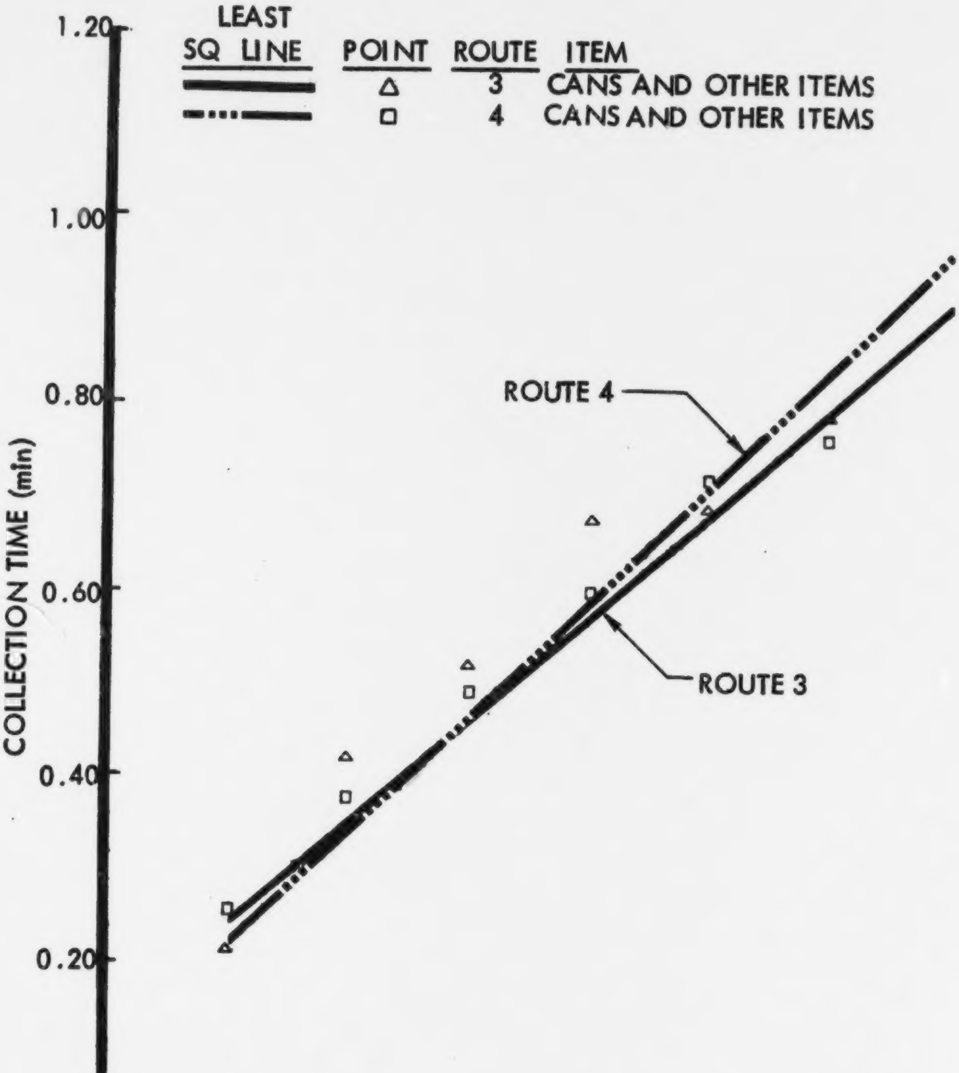


FIGURE 9

COLLECTION TIME
CANS ONLY - AREA C

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 11

COLLECTION TIME
ITEMS - AREA B

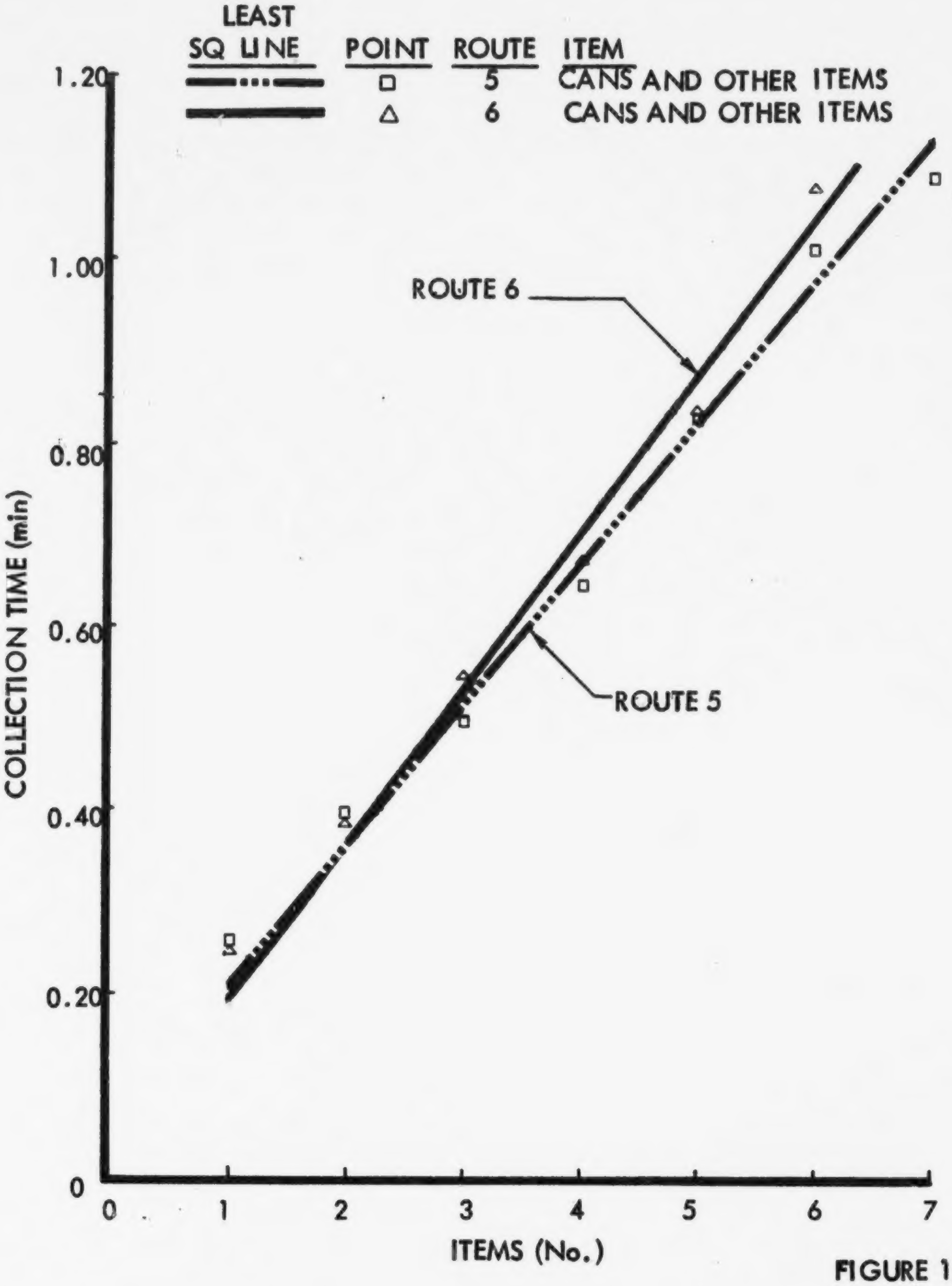
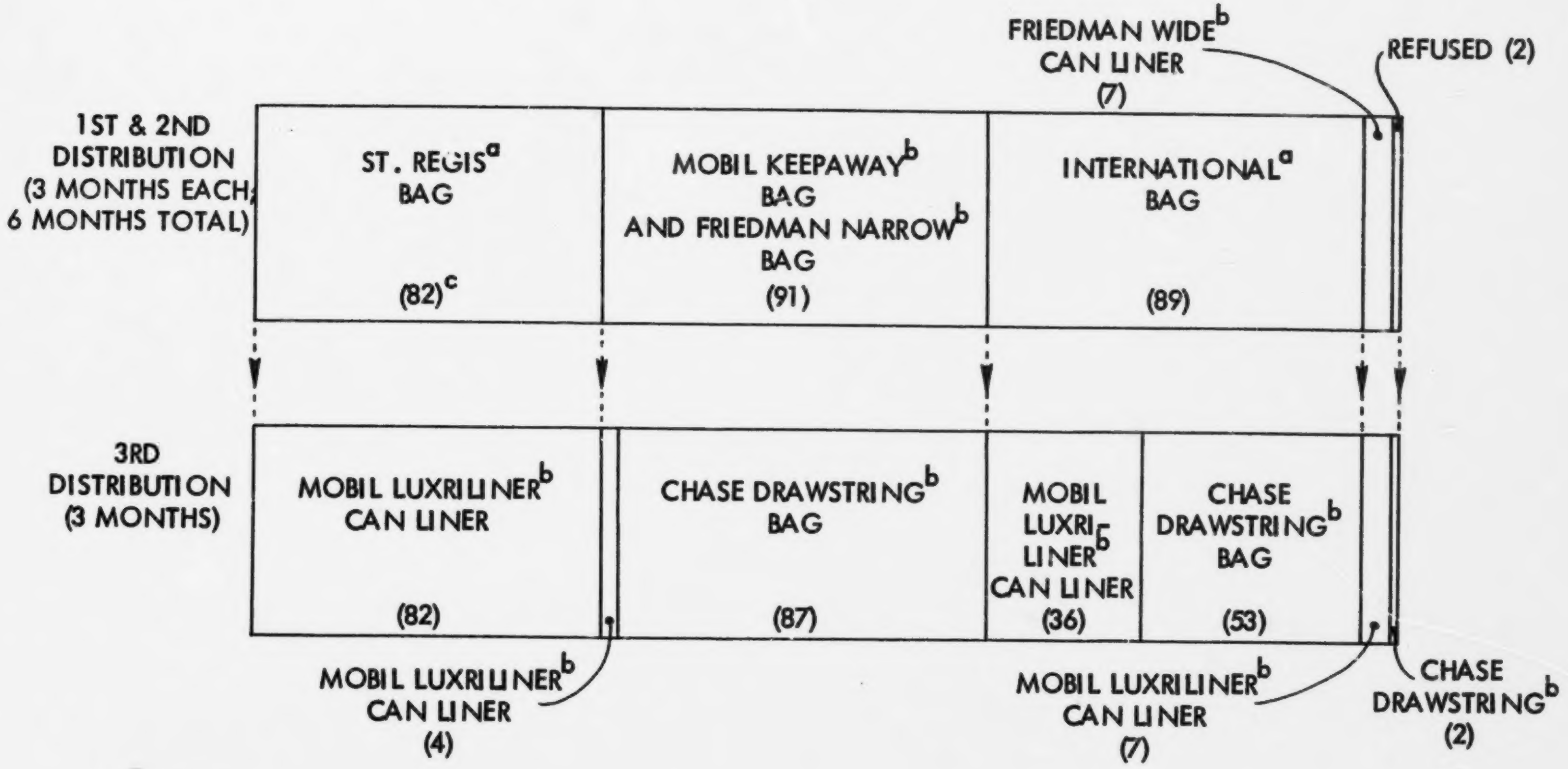


FIGURE 12

COLLECTION TIME
ITEMS - AREA C

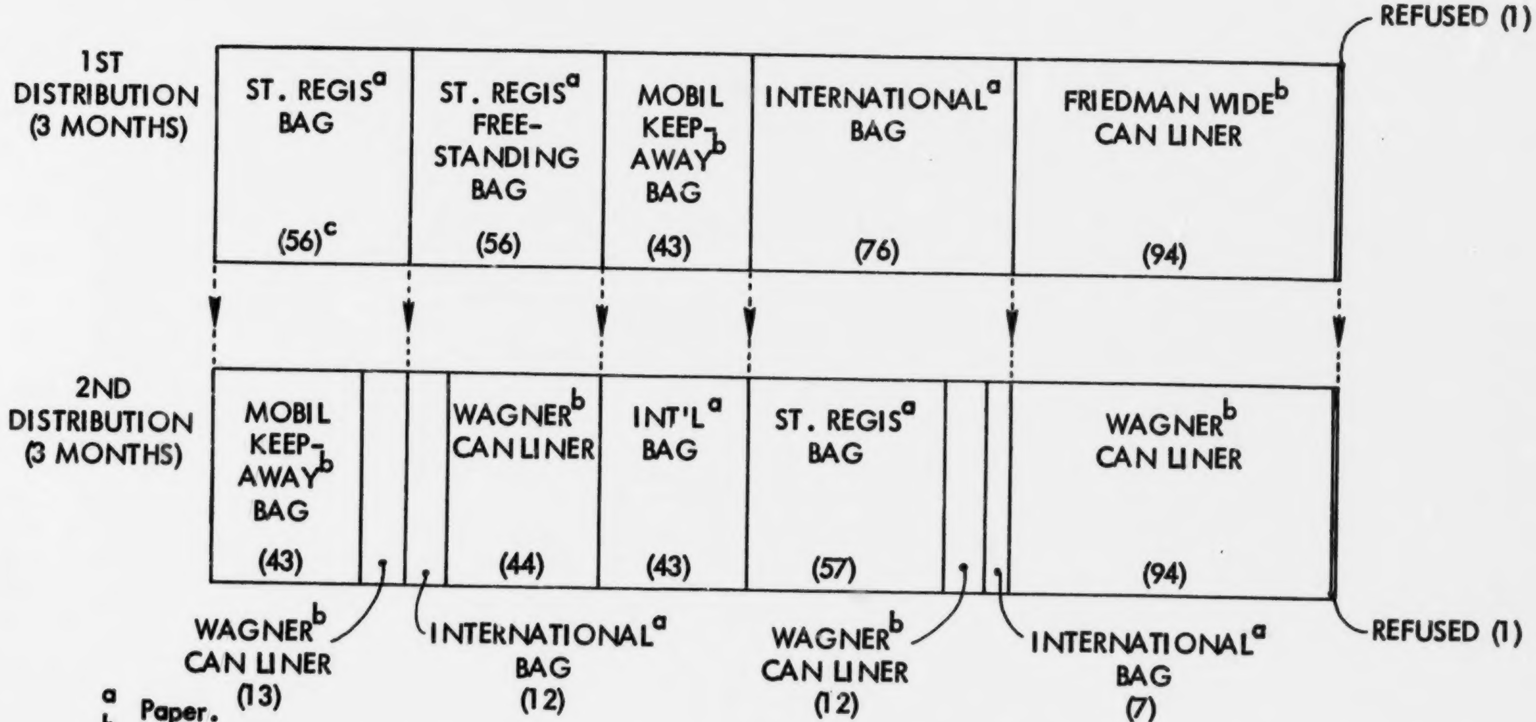
CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


FRIEDMAN WIDE[b]
CAN LINER
(7)
REFUSED (2)
1ST & 2ND
DISTRIBUTION
(3 MONTHS EACH;
6 MONTHS TOTAL)
ST. REGIS[a]
BAG
(82)[c]
MOBIL KEEPAWAY[b]
BAG
AND FRIEDMAN NARROW[b]
BAG
(91)
INTERNATIONAL[a]
BAG
(89)
3RD
DISTRIBUTION
(3 MONTHS)
MOBIL LUXRILINER[b]
CAN LINER
(82)
CHASE DRAWSTRING[b]
BAG
(87)
MOBIL
LUXRI
LINER[b]
CAN LINER
(36)
CHASE
DRAWSTRING[b]
BAG
(53)
MOBIL LUXRILINER[b]
CAN LINER
(4)
MOBIL LUXRILINER[b]
CAN LINER
(7)
CHASE
DRAWSTRING[b]
(2)

[a] Paper.
[b] Polyethylene.
[c] Number in parentheses designates the number of units using the system.

FIGURE 13

BAG AND LINER DISTRIBUTION
ROUTE A1

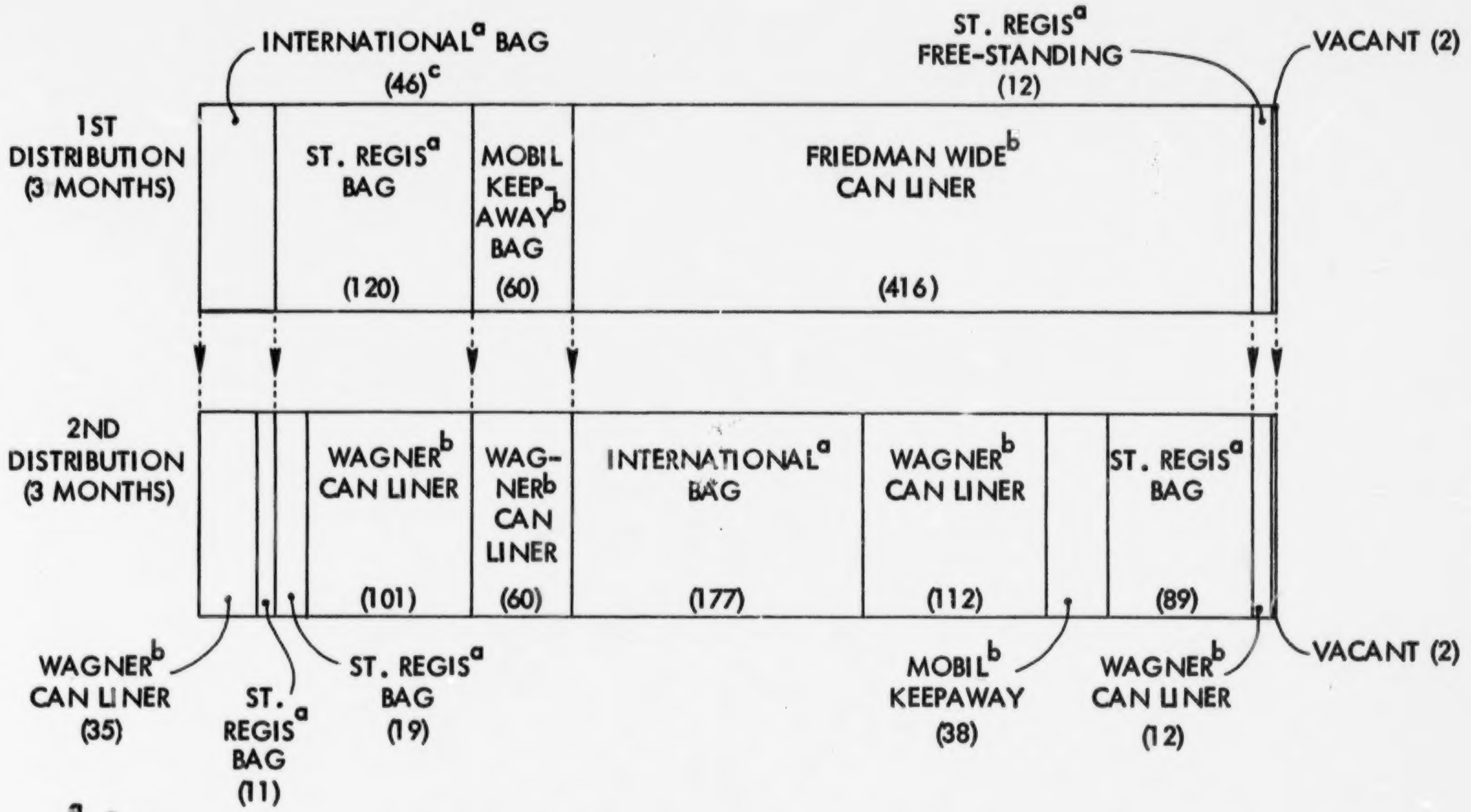

1ST DISTRIBUTION (3 MONTHS)
ST. REGIS[a] BAG (56)[c]
ST. REGIS[a] FREE-STANDING BAG (56)
MOBIL KEEP-AWAY[b] BAG (43)
INTERNATIONAL[a] BAG (76)
FRIEDMAN WIDE[b] CAN LINER (94)
REFUSED (1)
2ND DISTRIBUTION (3 MONTHS)
MOBIL KEEP-AWAY[b] BAG (43)
WAGNER[b] CAN LINER (13)
INTERNATIONAL[a] BAG (12)
WAGNER[b] CAN LINER (44)
INT'L[a] BAG (43)
ST. REGIS[a] BAG (57)
WAGNER[b] CAN LINER (12)
INTERNATIONAL[a] BAG (7)
WAGNER[b] CAN LINER (94)
REFUSED (1)

[a] Paper.
[b] Polyethylene.
[c] Number in parenthesis designates the number of units using the system.

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 14

BAG AND LINER DISTRIBUTION
ROUTE B4



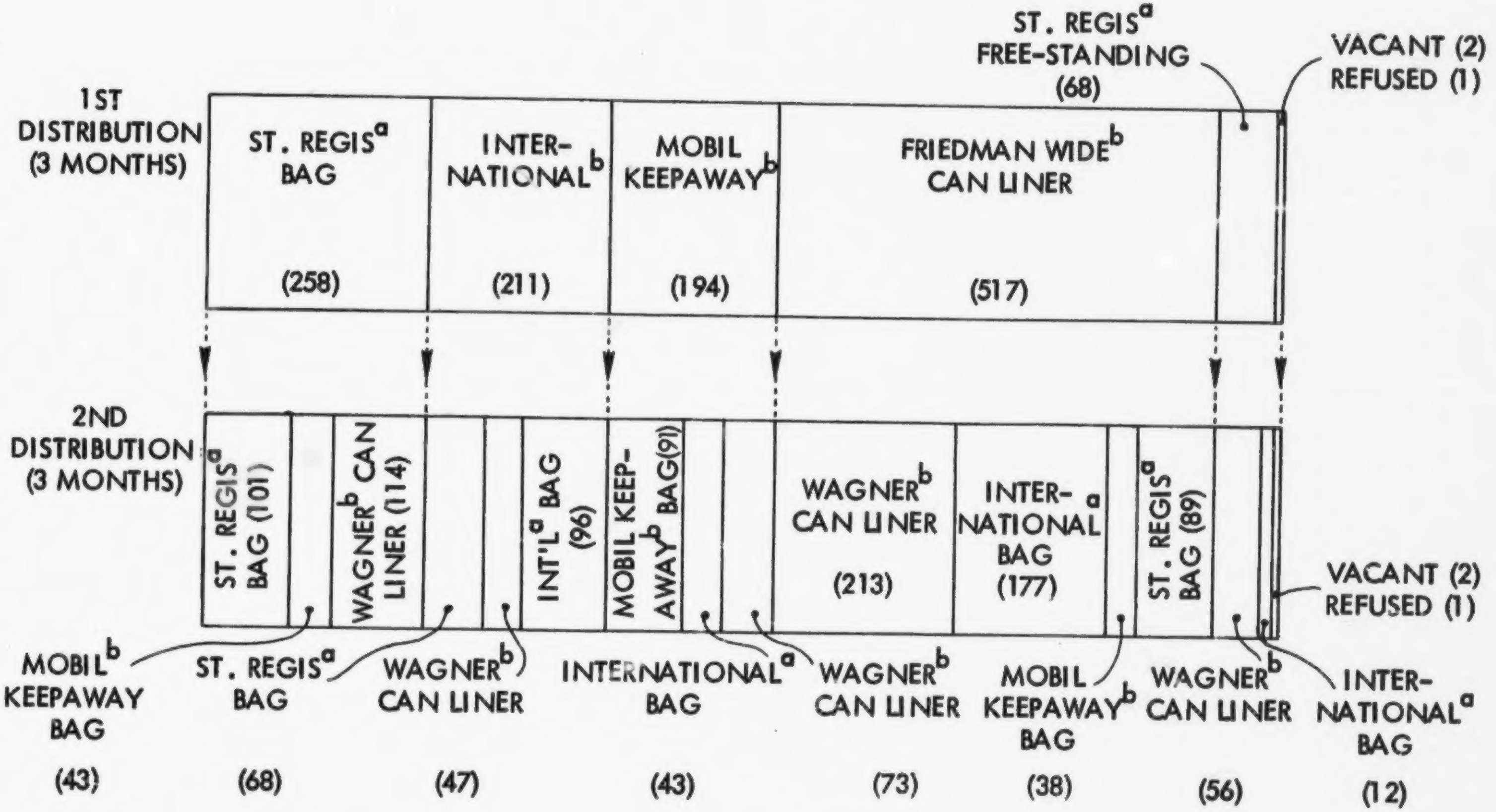
INTERNATIONAL[a] BAG (46)[c]
ST. REGIS[a] FREE-STANDING (12)
VACANT (2)
1ST DISTRIBUTION (3 MONTHS)
ST. REGIS[a] BAG (120)
MOBIL KEEP-AWAY[b] BAG (60)
FRIEDMAN WIDE[b] CAN LINER (416)
2ND DISTRIBUTION (3 MONTHS)
WAGNER[b] CAN LINER (101)
WAG-NER[b] CAN LINER (60)
INTERNATIONAL[a] BAG (177)
WAGNER[b] CAN LINER (112)
ST. REGIS[a] BAG (89)
WAGNER[b] CAN LINER (35)
ST. REGIS[a] BAG (11)
ST. REGIS[a] BAG (19)
MOBIL[b] KEEPAWAY (38)
WAGNER[b] CAN LINER (12)
VACANT (2)

[a] Paper.
[b] Polyethylene.
[c] Number in parenthesis designates the number of units using the system.

FIGURE 15

BAG AND LINER DISTRIBUTION
ROUTE C5

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


1ST DISTRIBUTION (3 MONTHS)
ST. REGIS^a BAG (258)
INTER-NATIONAL^b (211)
MOBIL KEEPAWAY^b (194)
FRIEDMAN WIDE^b CAN LINER (517)
ST. REGIS^a FREE-STANDING (68)
VACANT (2) REFUSED (1)
2ND DISTRIBUTION (3 MONTHS)
ST. REGIS^a BAG (101)
WAGNER^b CAN LINER (114)
INT'L^a BAG (96)
MOBIL KEEP-AWAY^b BAG(91)
WAGNER^b CAN LINER (213)
INTER-NATIONAL^a BAG (177)
ST. REGIS^a BAG (89)
VACANT (2) REFUSED (1)
MOBIL^b KEEPAWAY BAG (43)
ST. REGIS^a BAG (68)
WAGNER^b CAN LINER (47)
INTERNATIONAL^a BAG (43)
WAGNER^b CAN LINER (73)
MOBIL KEEPAWAY^b BAG (38)
WAGNER^b CAN LINER (56)
INTER-NATIONAL^a BAG (12)

[a] Paper.
[b] Polyethylene.
[c] Number in parenthesis designates the number of units using the system.
NOTE: See Figure 13 for the 3rd Distribution Summary.

FIGURE 16

BAG AND LINER DISTRIBUTION SUMMARY
ROUTES A1, B4, C5

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

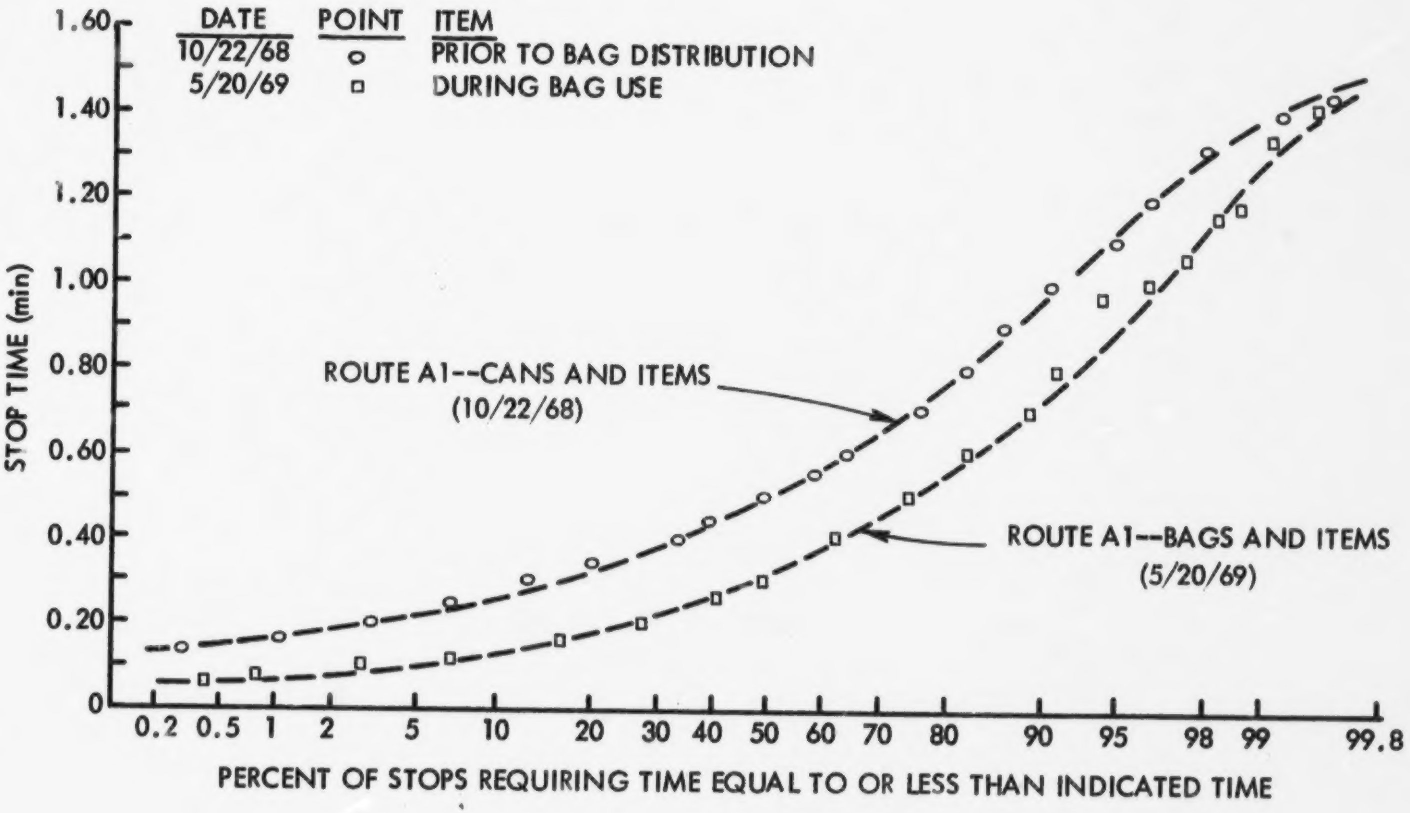
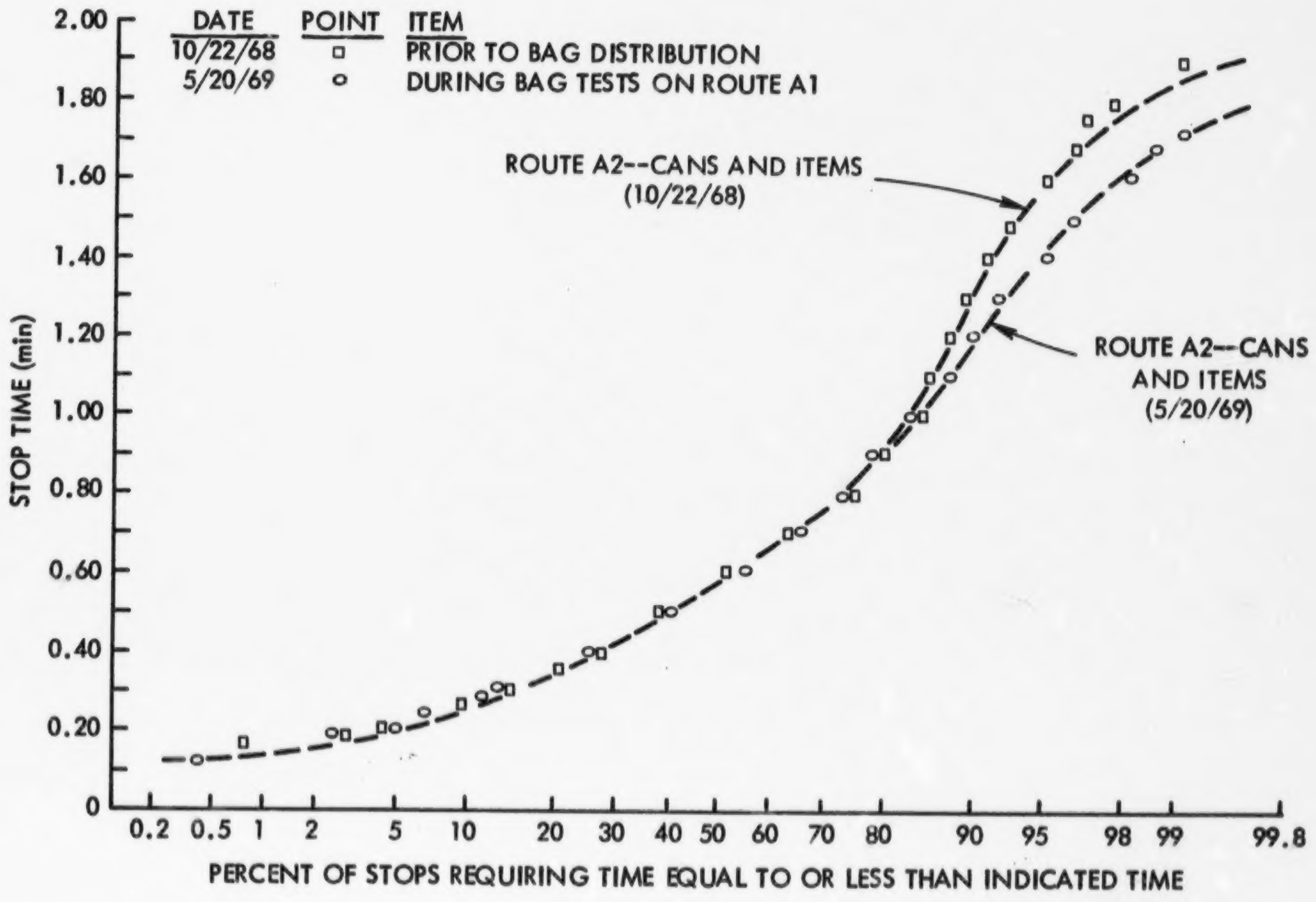


FIGURE 17

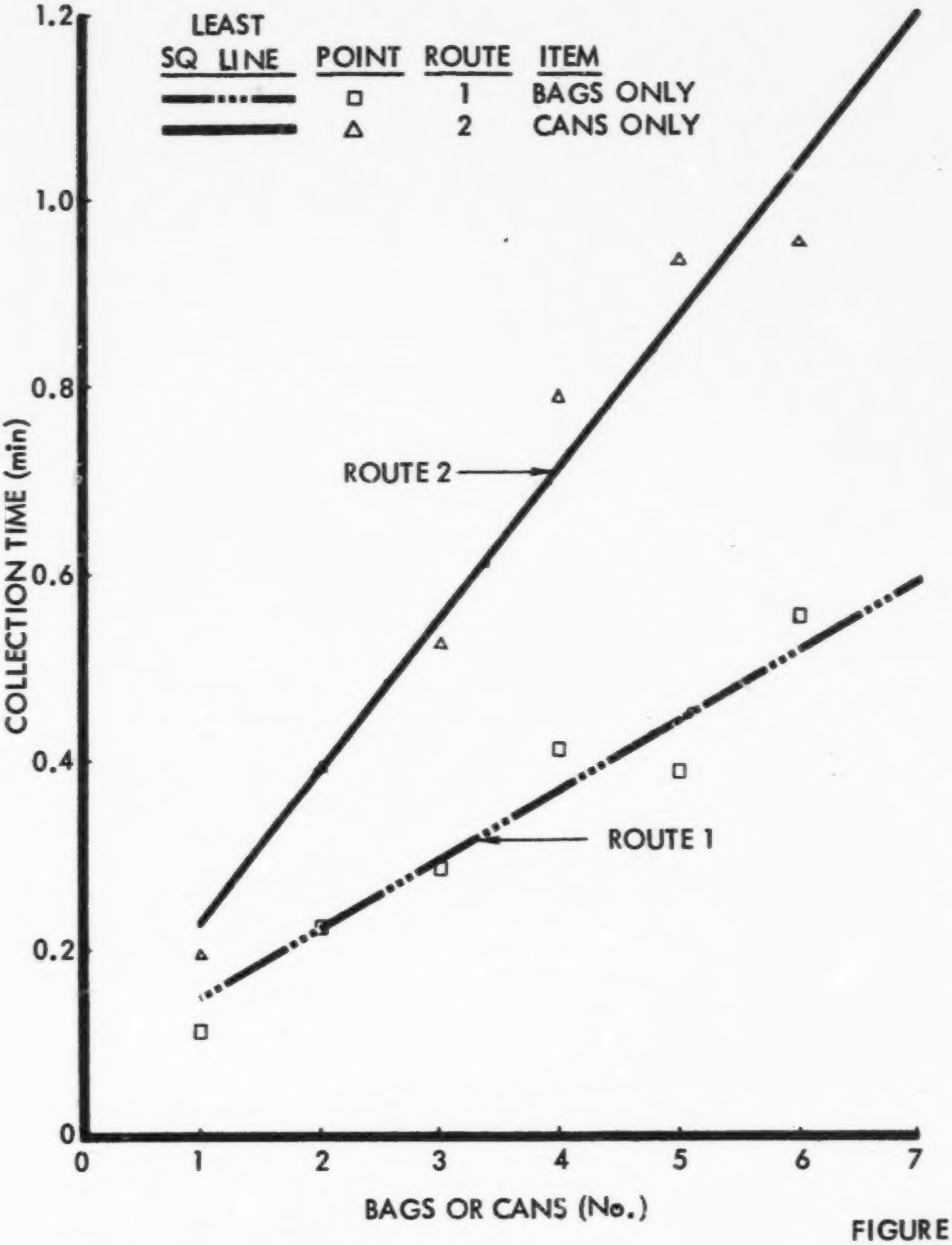
COLLECTION TIME
DISTRIBUTION, ROUTE A1

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

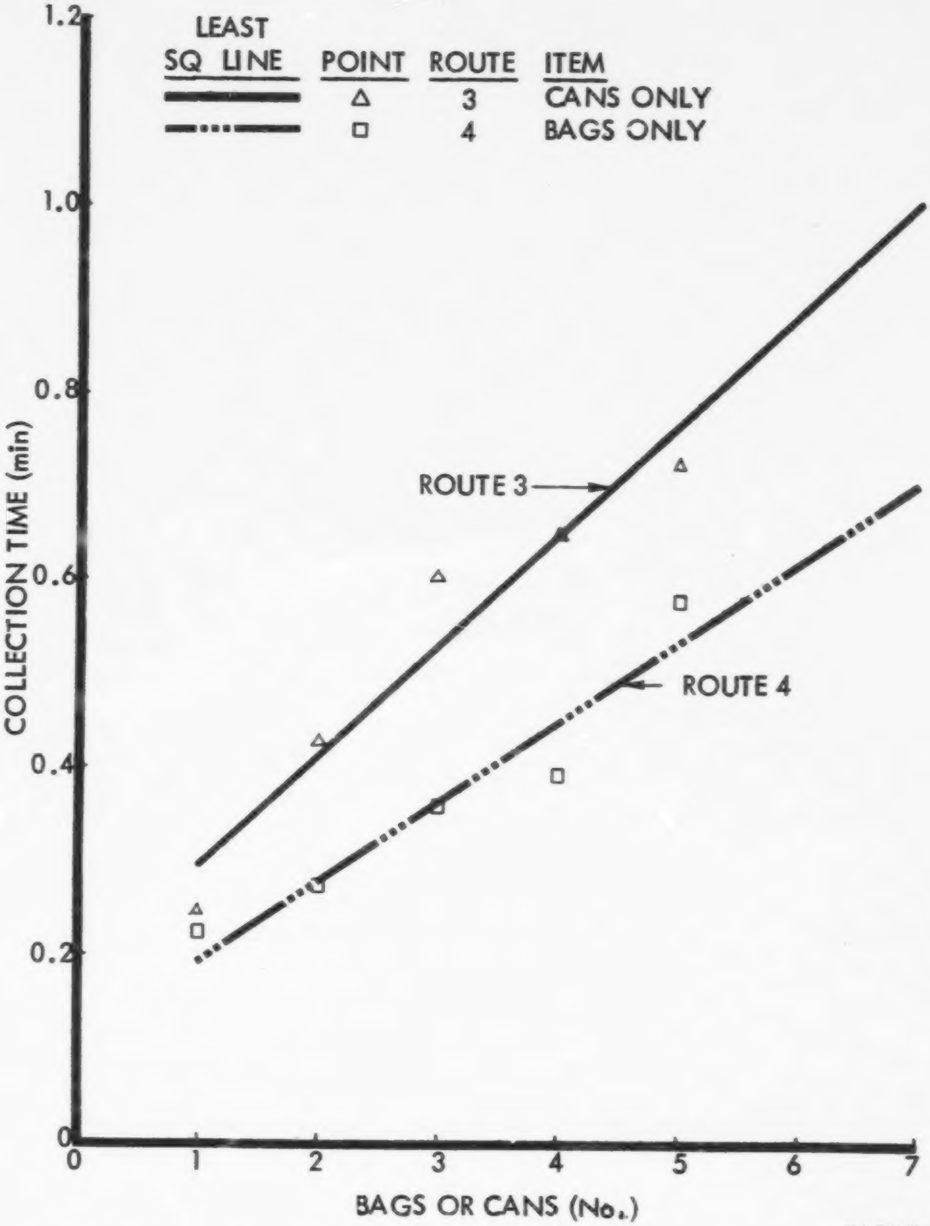
FIGURE 18
COLLECTION TIME
DISTRIBUTION, ROUTE A2



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 19

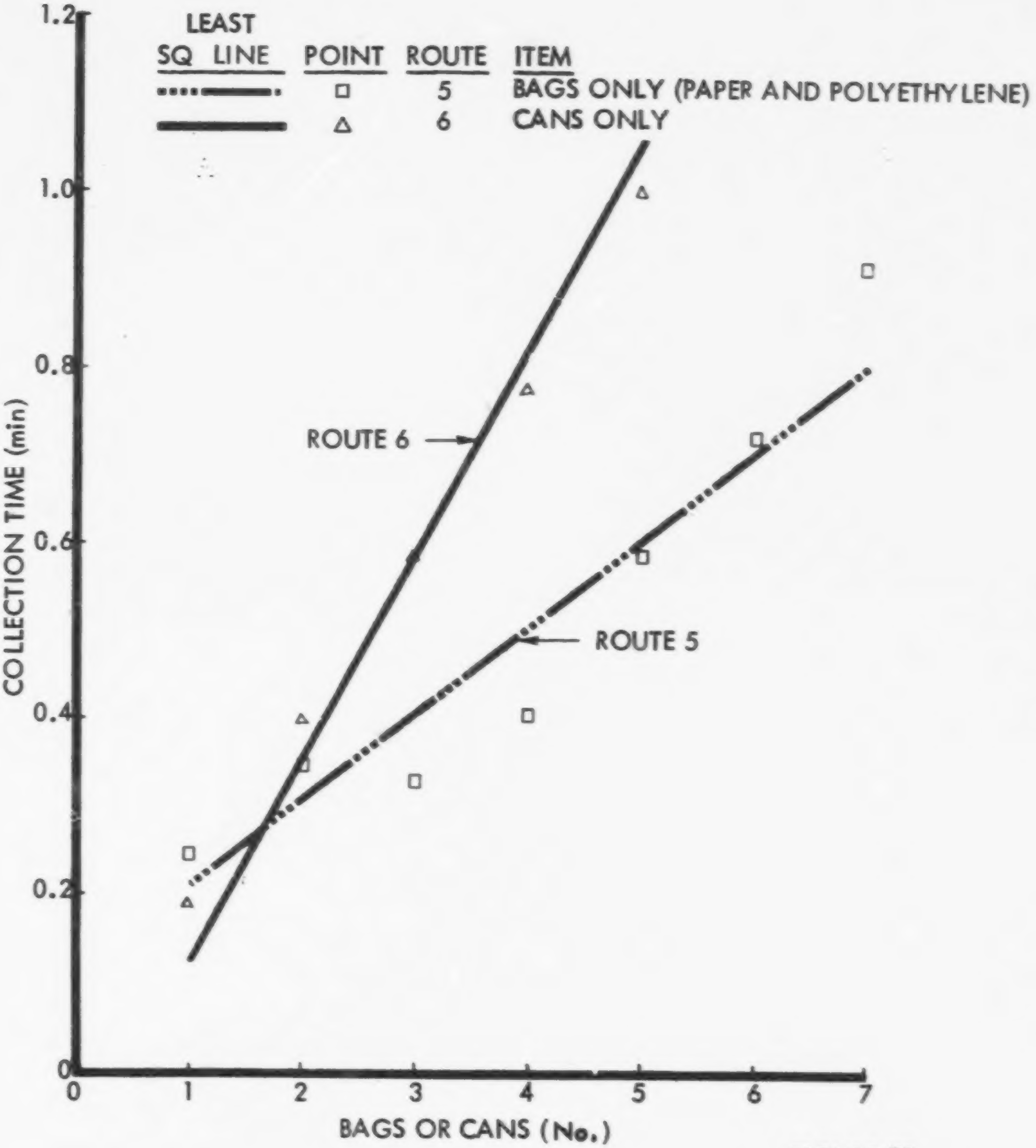
COLLECTION TIME
BAGS AND CANS - AREA A



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 20

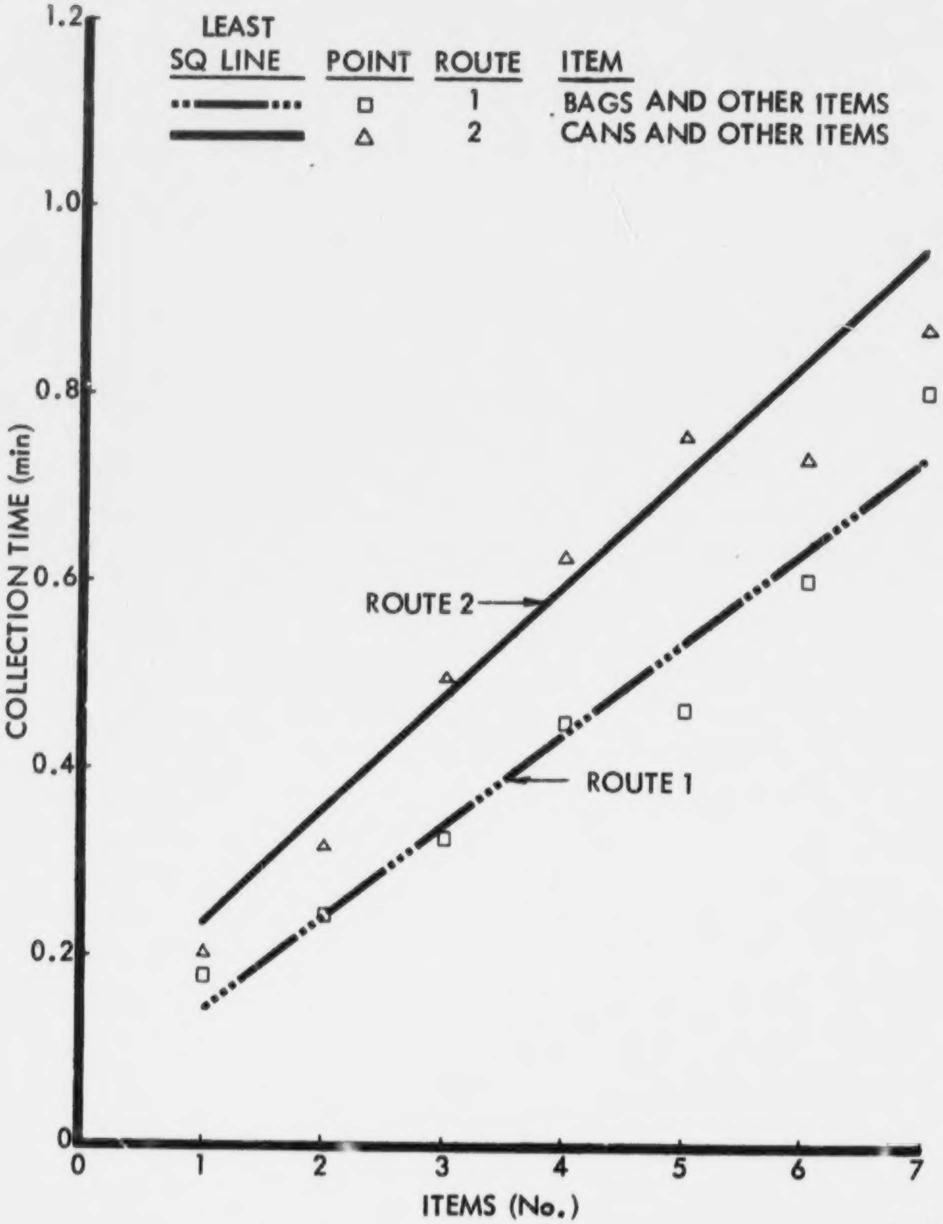
COLLECTION TIME
BAGS AND CANS - AREA B



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 21

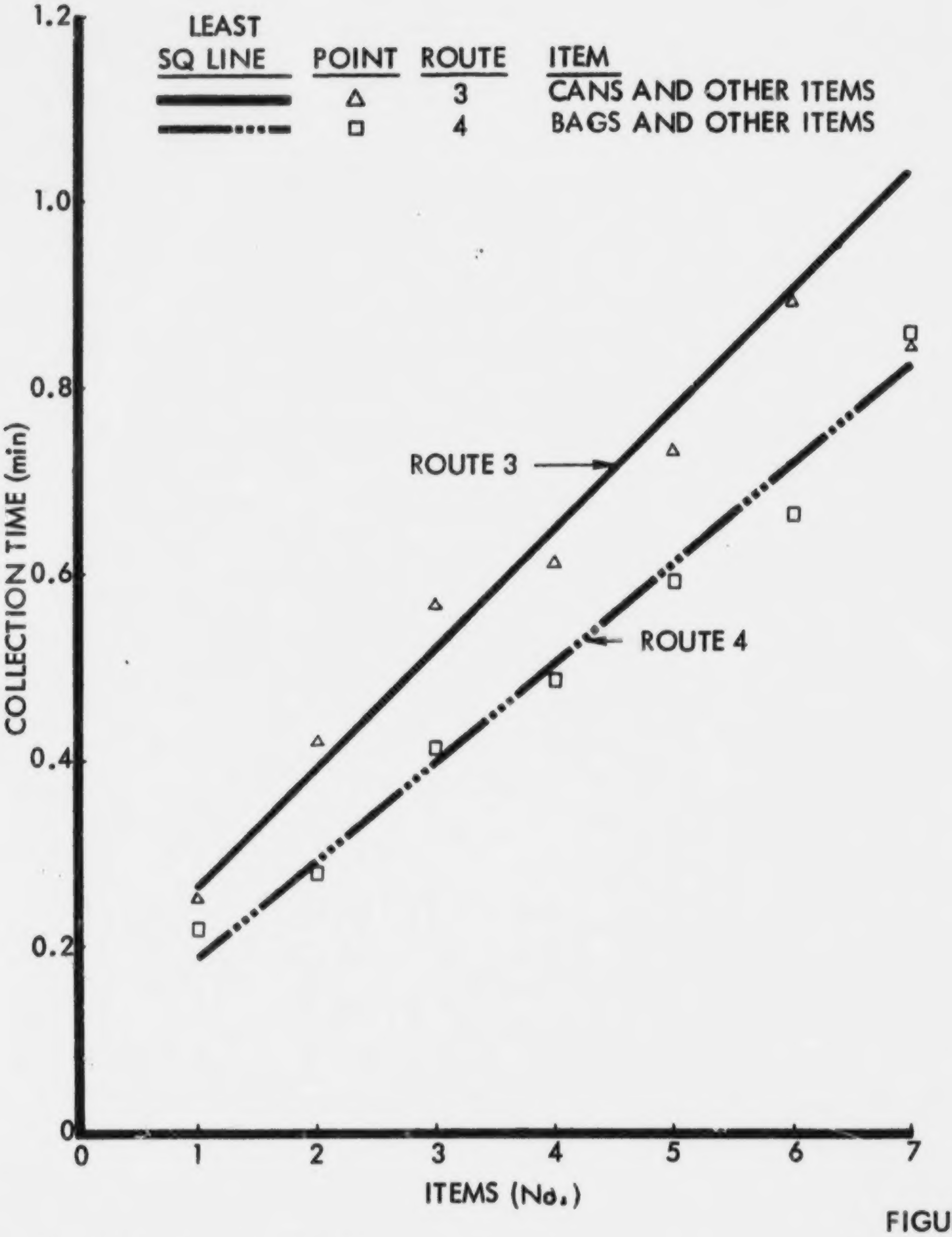
COLLECTION TIME
BAGS AND CANS - AREA C



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 22

COLLECTION TIME
ITEMS - AREA A



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 23
COLLECTION TIME
ITEMS - AREA B

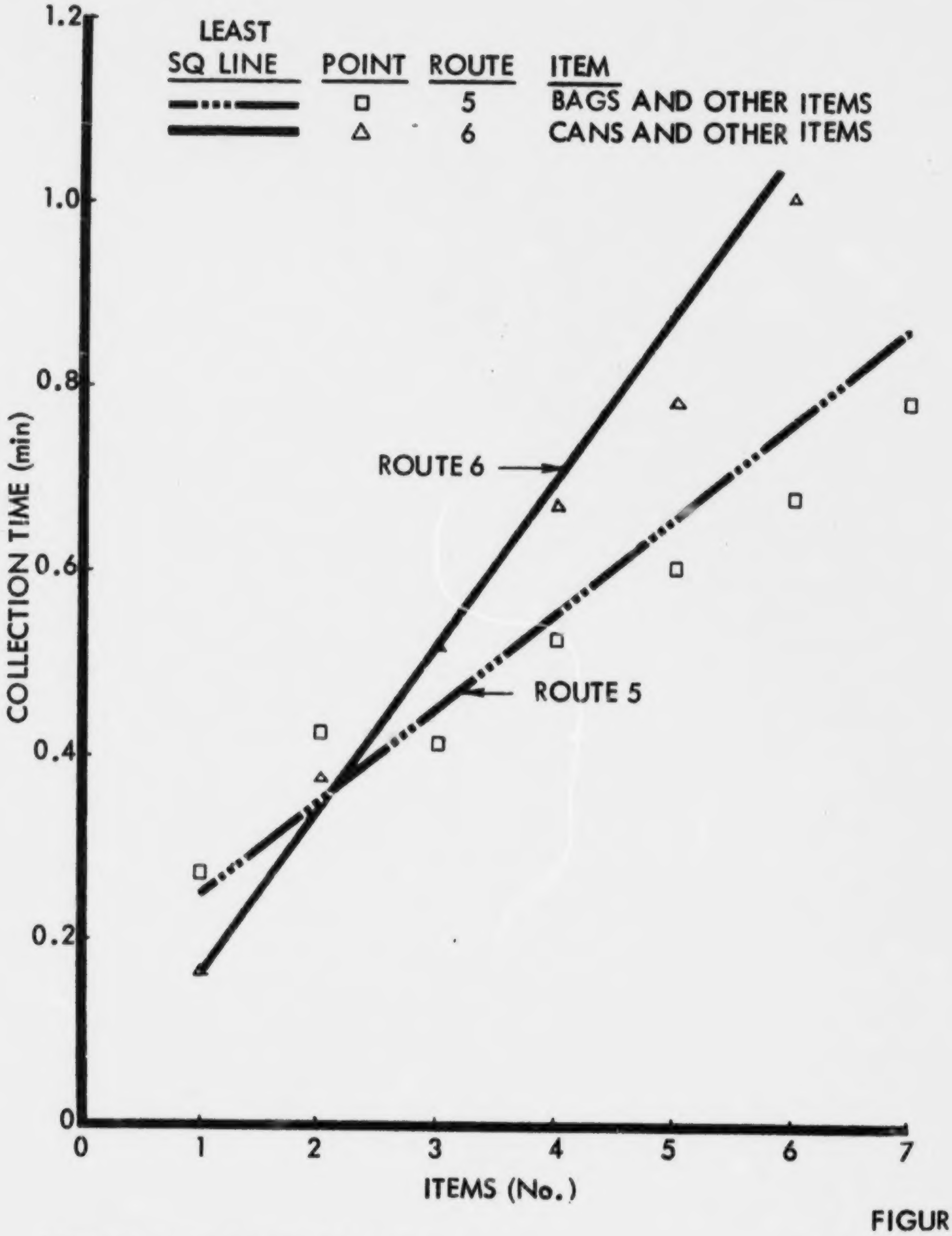


FIGURE 24

COLLECTION TIME
ITEMS - AREA C

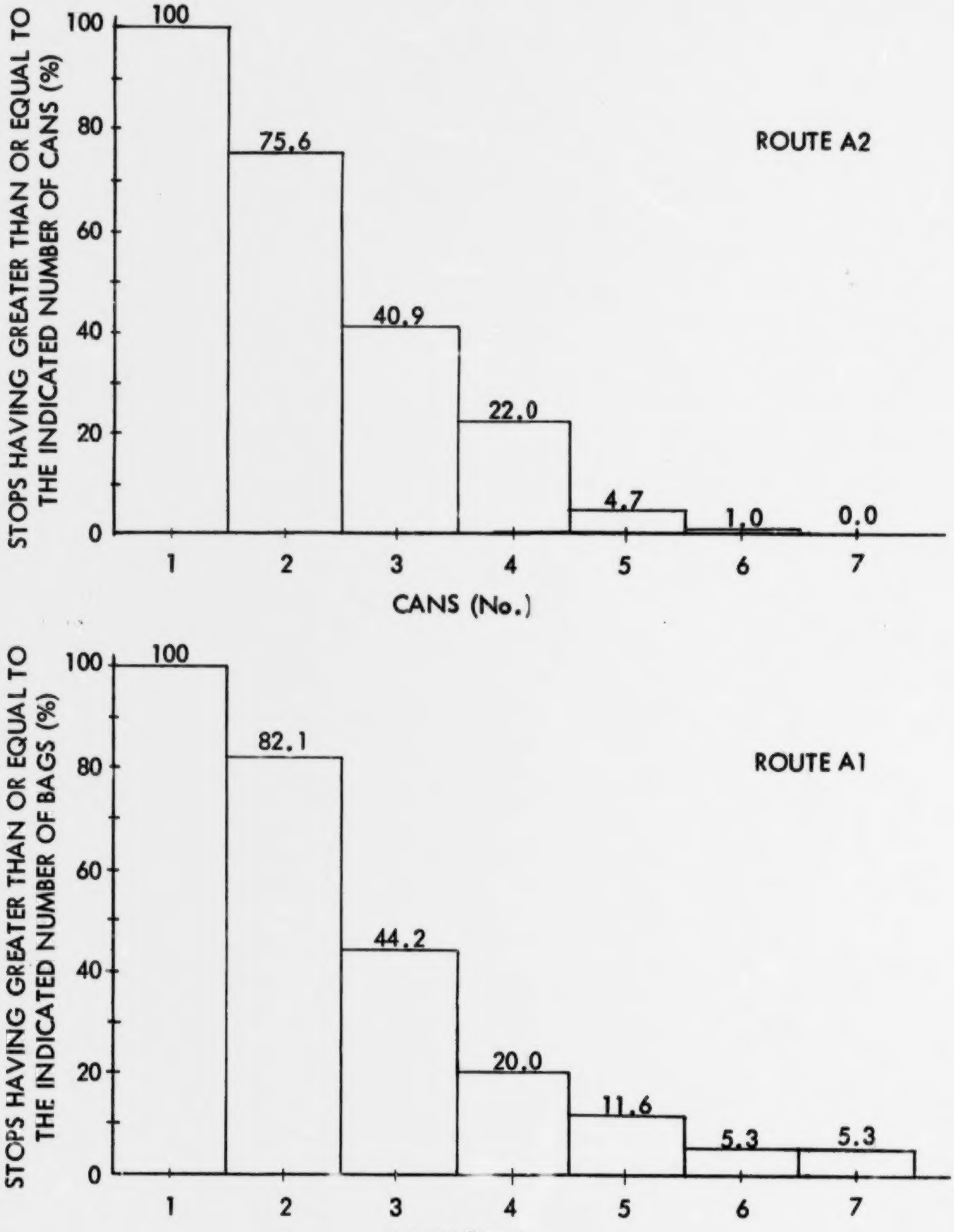


FIGURE 25

DISTRIBUTION OF CANS AND BAGS AT COLLECTION STOPS

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

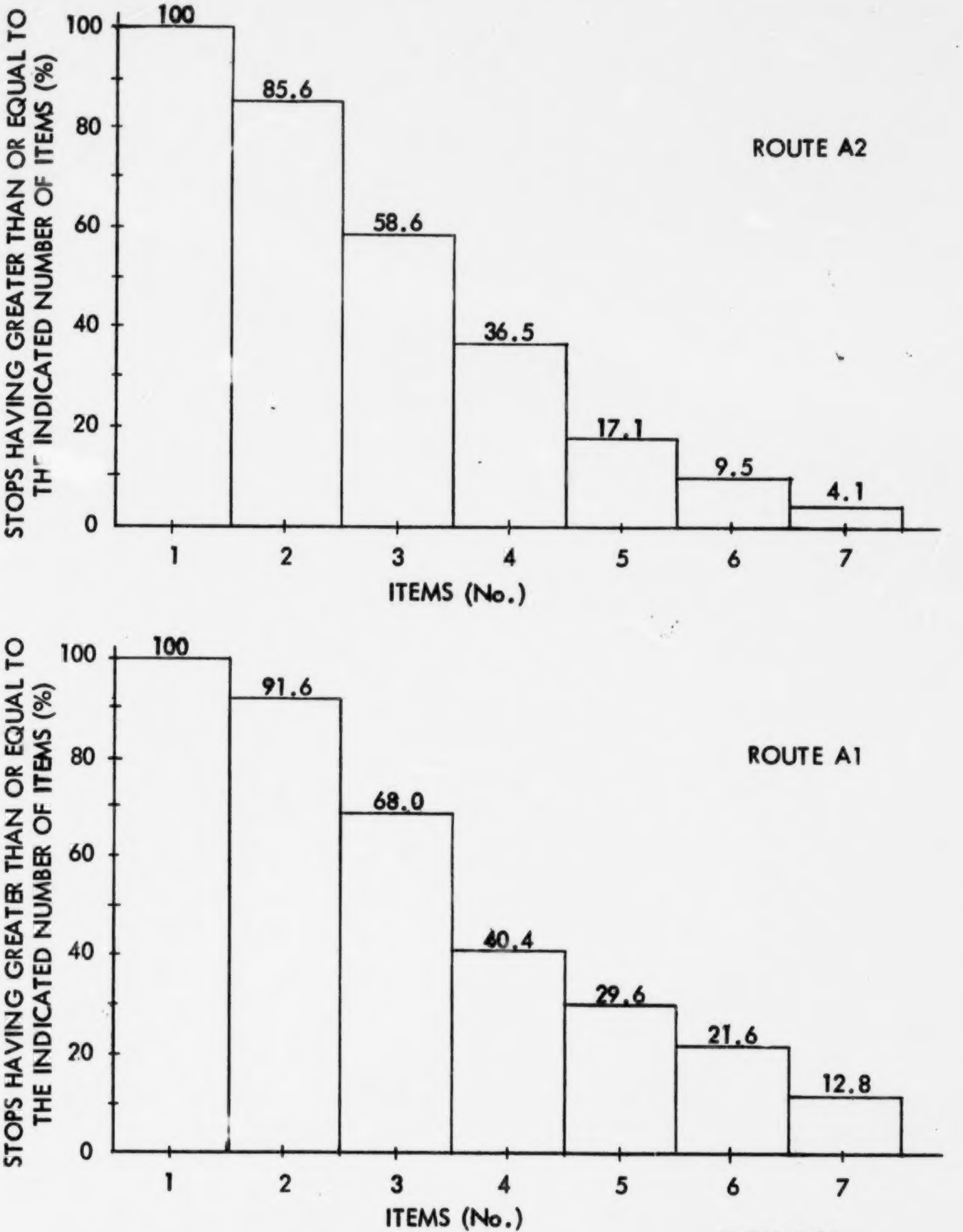
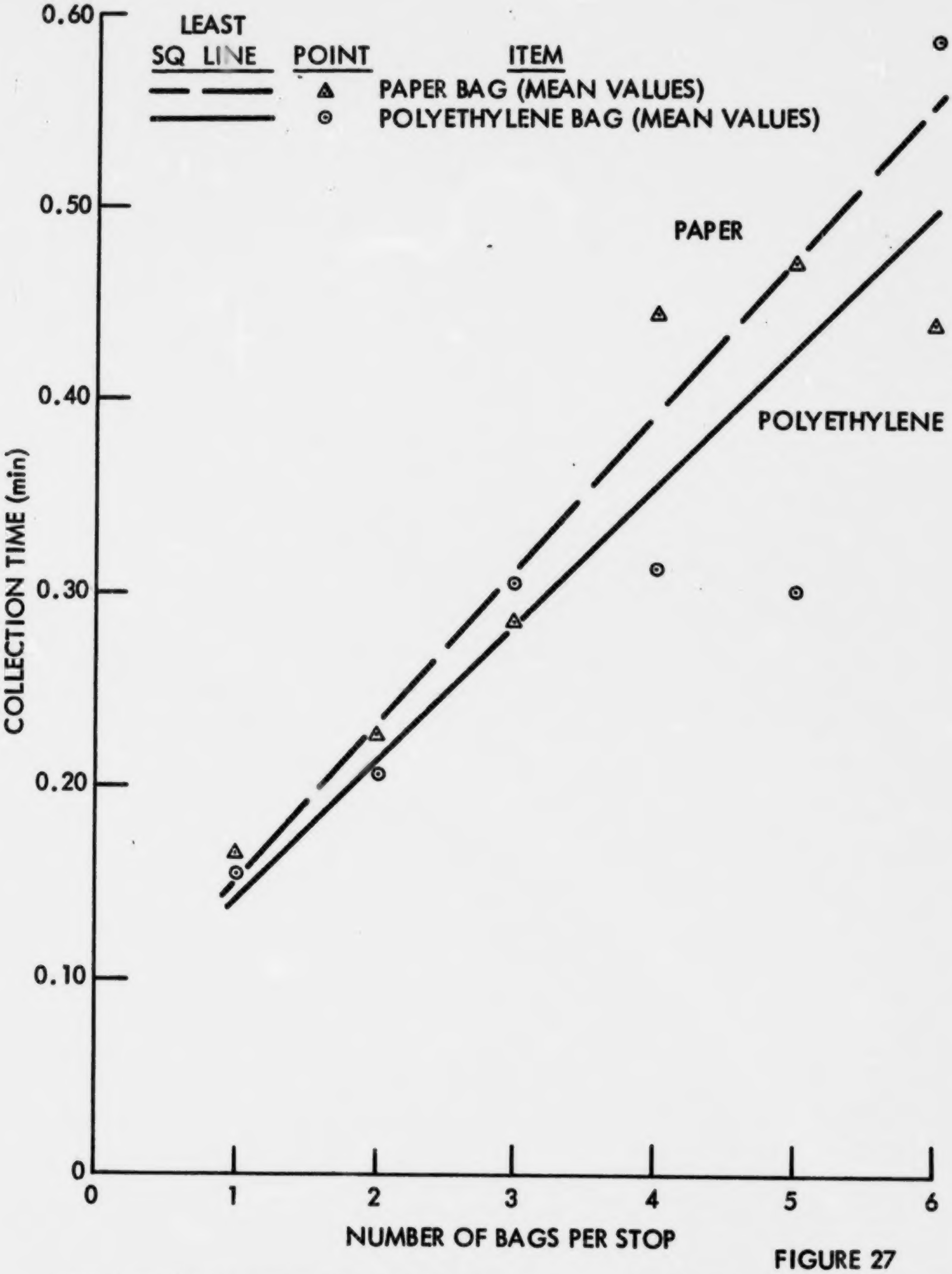


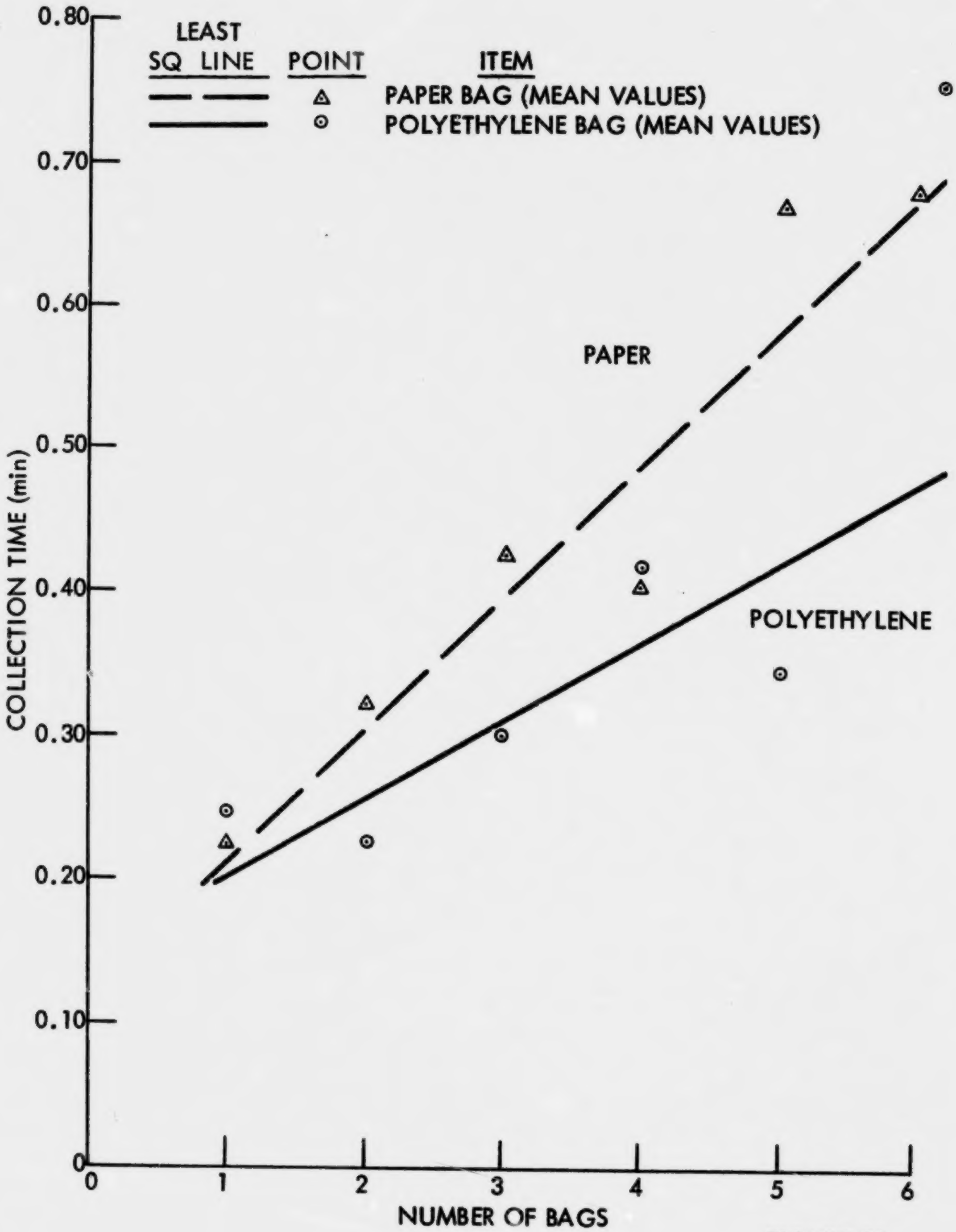
FIGURE 26
DISTRIBUTION OF CONTAINERS
AT COLLECTION STOPS

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 27
COLLECTION TIME FOR BAGS
ROUTE A1



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 28
COLLECTION TIME FOR BAGS
ROUTE B4

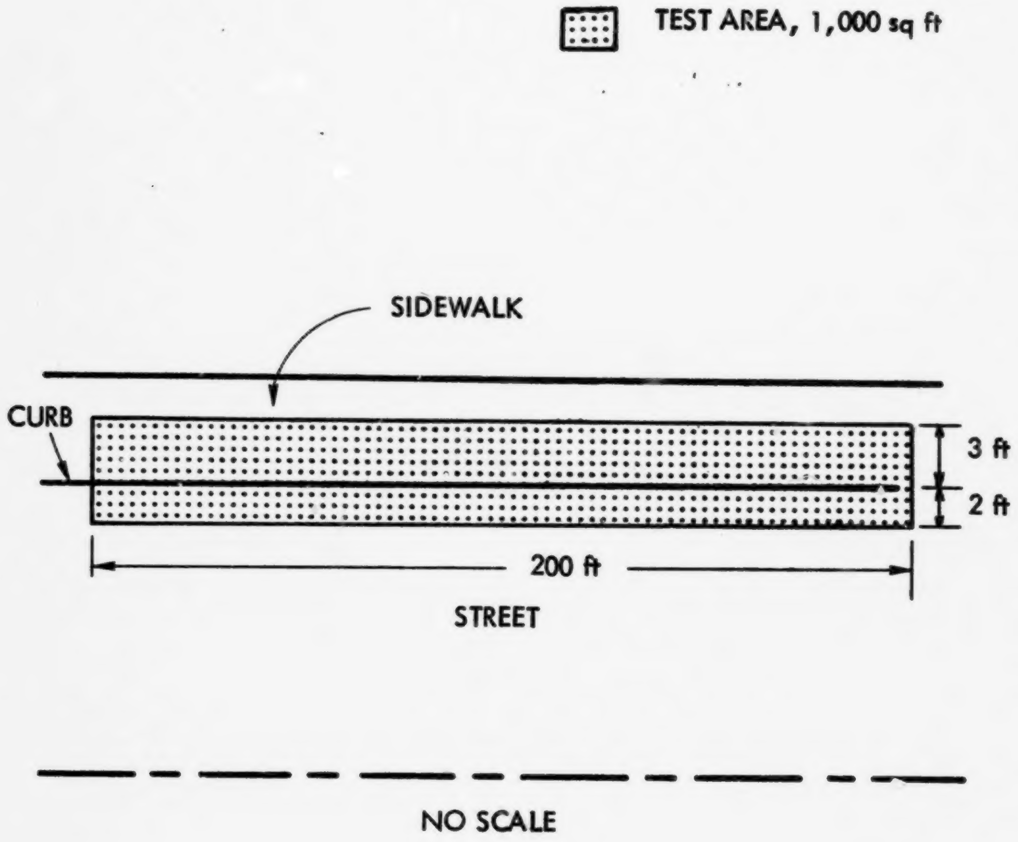
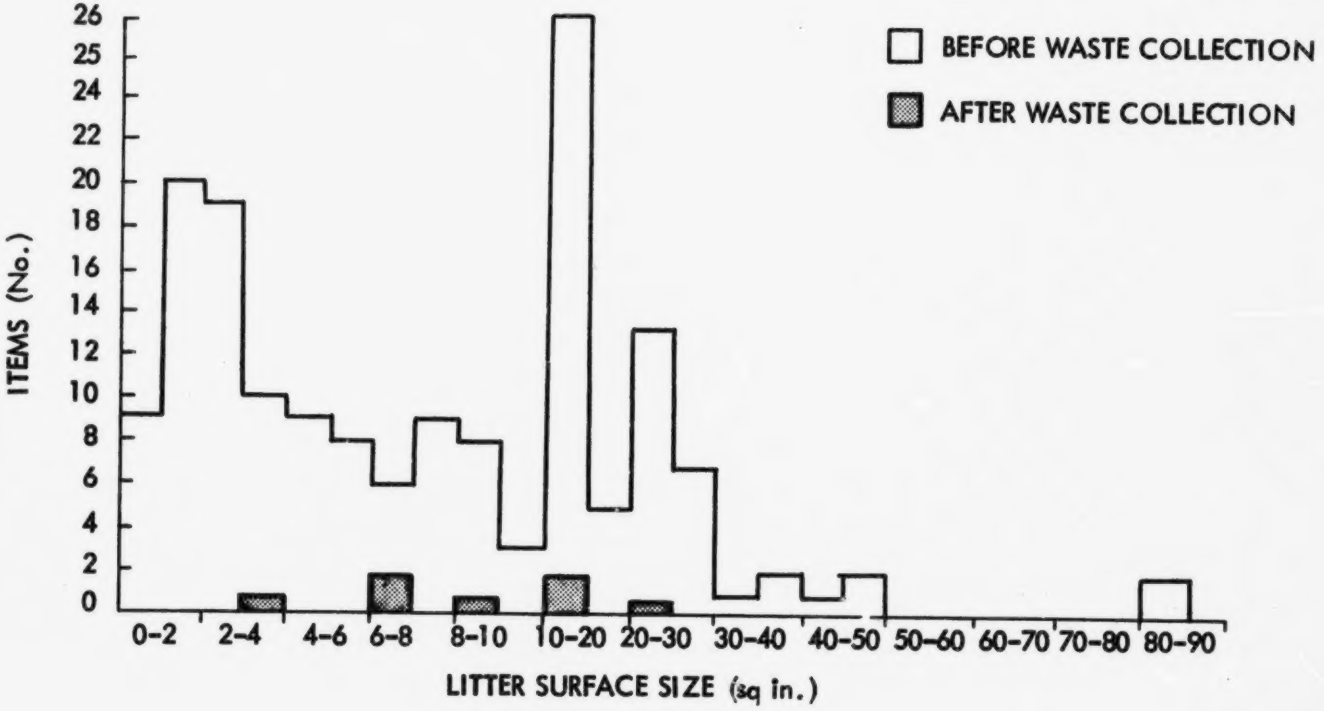

▦ TEST AREA, 1,000 sq ft
SIDEWALK
CURB
3 ft
2 ft
200 ft
STREET
NO SCALE

FIGURE 29

CONFIGURATION OF TYPICAL TEST AREA FOR LITTER OBSERVATIONS

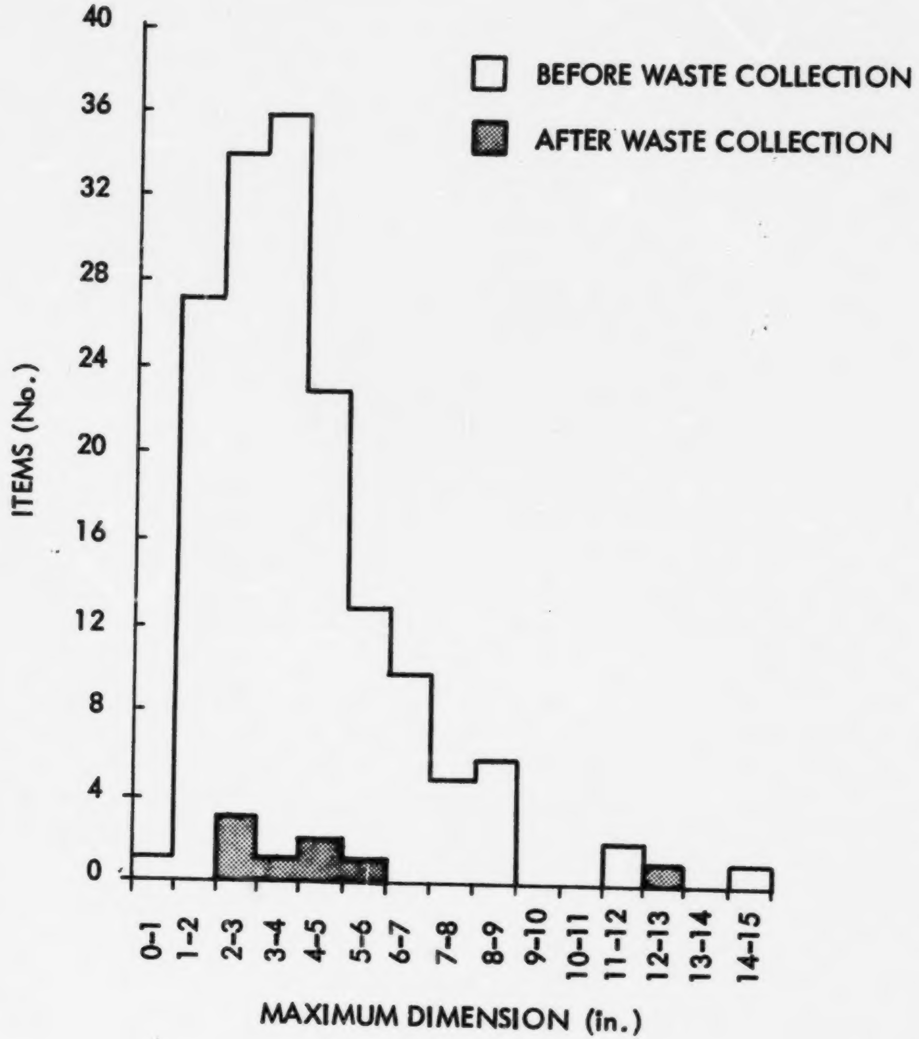
CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 30

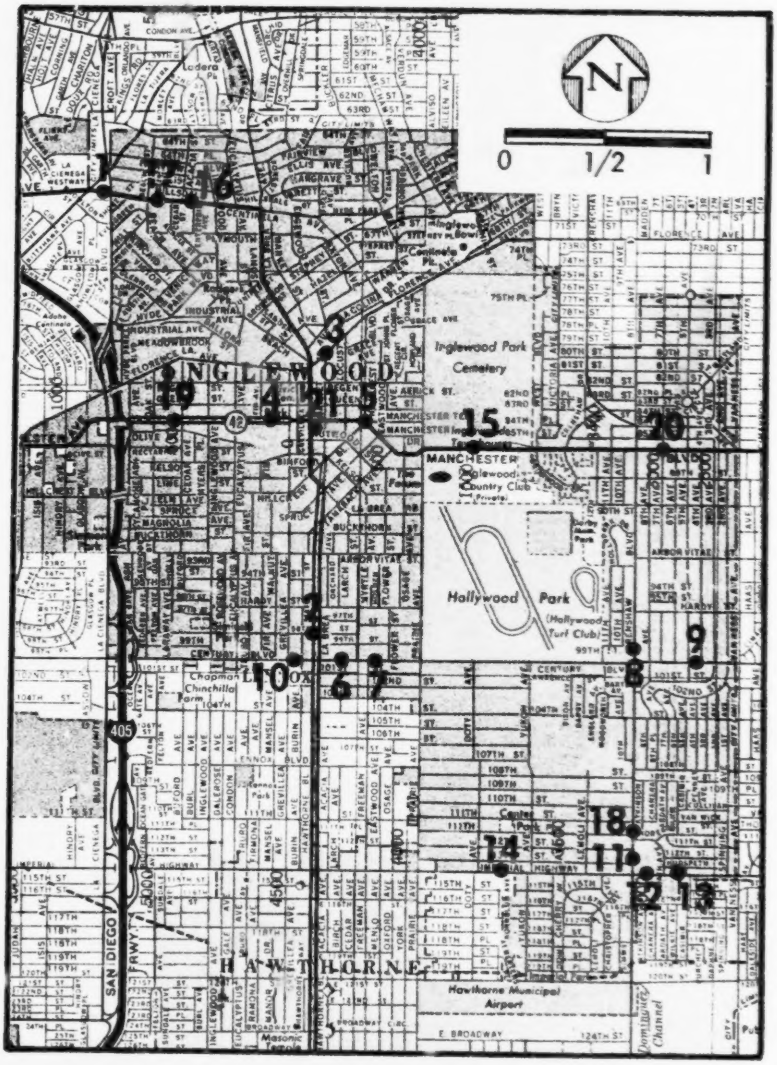
LITTER DISTRIBUTION



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 31

DISTRIBUTION OF LITTER
BY MAXIMUM DIMENSION



0
1/2
1
N
INGLEWOOD
HAWTHORNE
Inglewood Park Cemetery
Hollywood Park (Hollywood Turf Club)
Inglewood Country Club (Private)
Hawthorne Municipal Airport
Chapman Chinchilla Farm
MANCHESTER
SAN DIEGO FRWY.
405
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Note: Enumerated restaurants are identified in Table 28.

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 32

LOCATION OF RESTAURANTS TESTING BIN LINERS

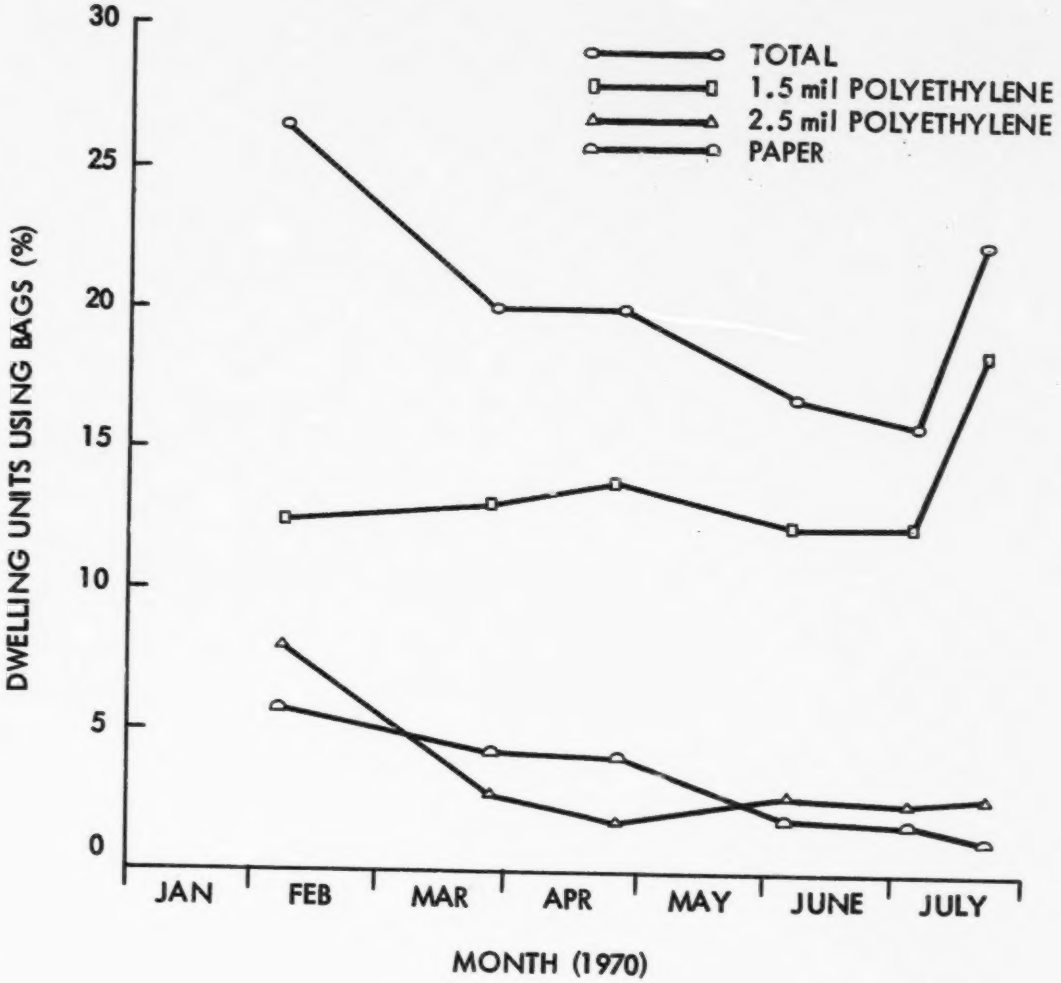


FIGURE 33

CONTINUED BAG USE, AREA B4
(326 SINGLE FAMILY UNITS)

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

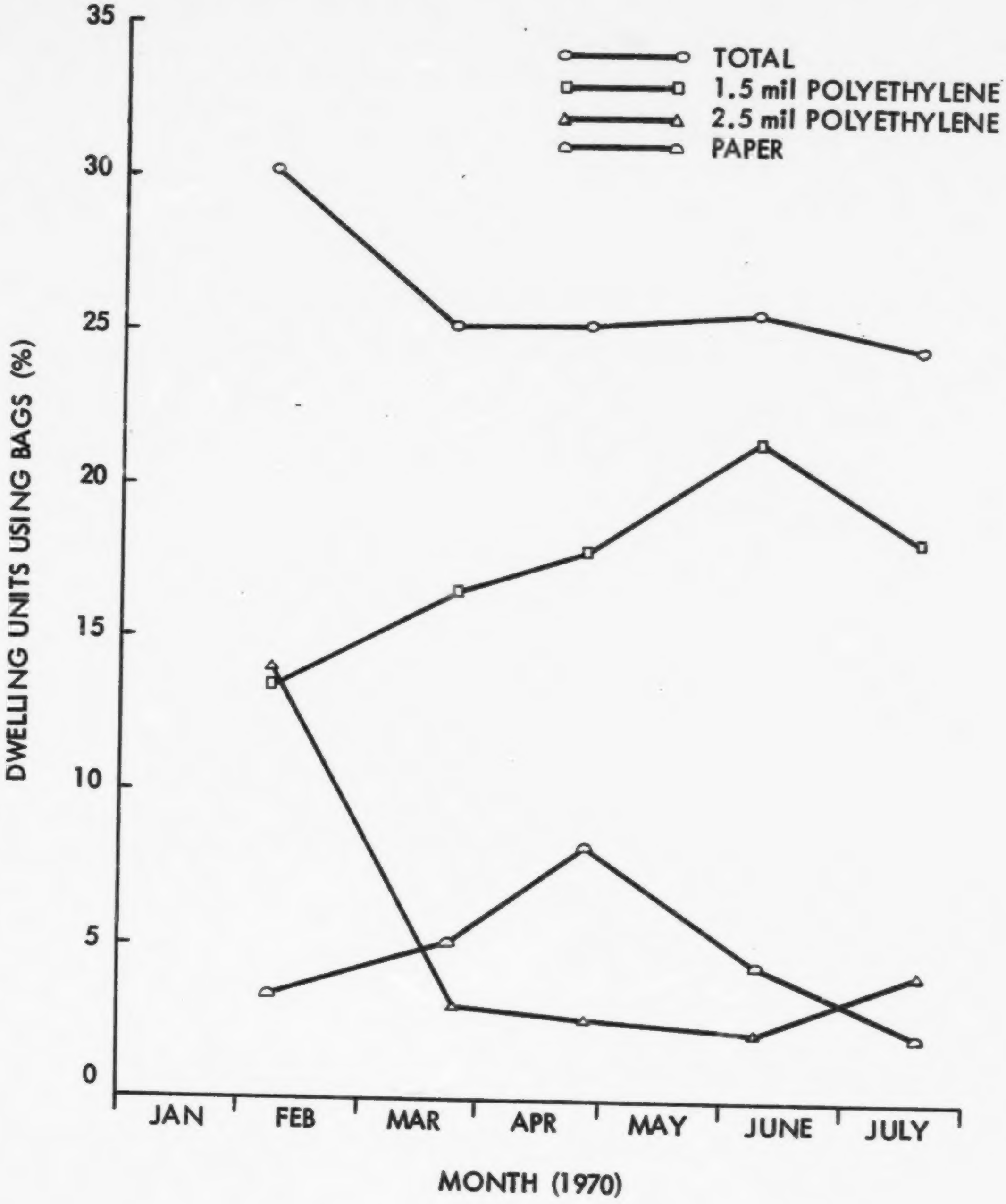


FIGURE 34

CONTINUED BAG USE, AREA C5
(85 SINGLE FAMILY UNITS,
102 APARTMENTS)

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

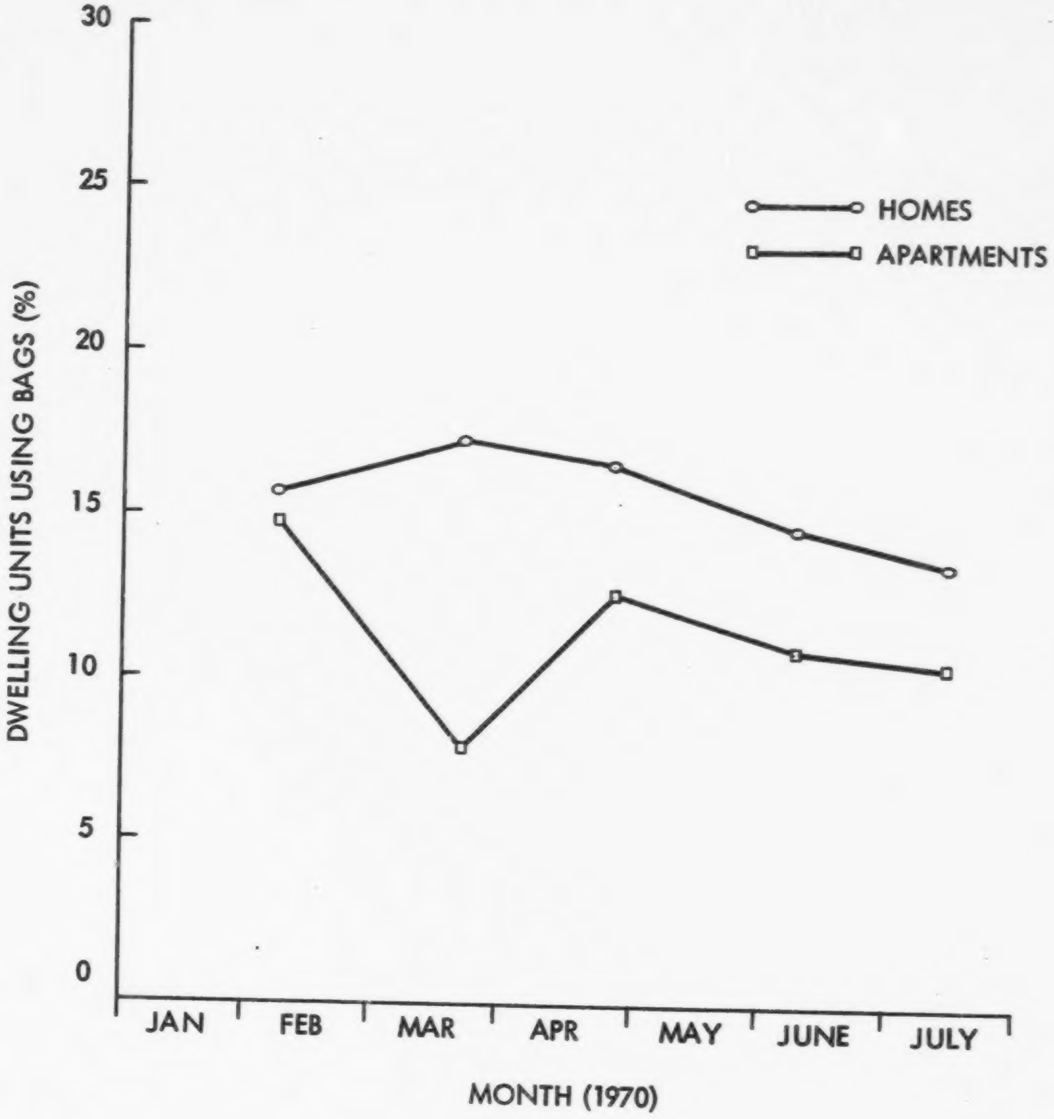
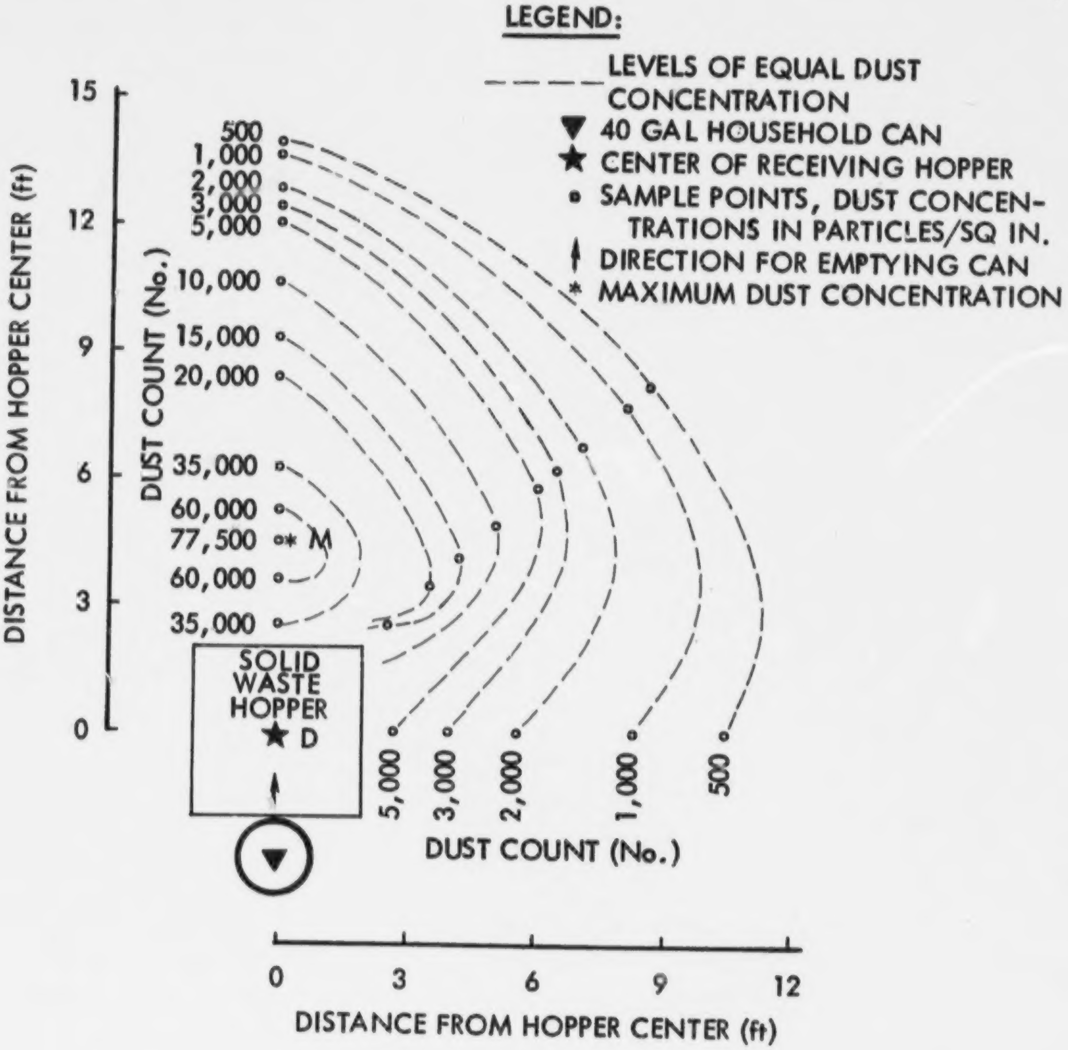


FIGURE 35

TOTAL BAG USAGE IN APARTMENTS AND SINGLE FAMILY UNITS, AREA C5 (85 SINGLE FAMILY UNITS, 102 APARTMENTS)

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 36

DUST PARTICLES GENERATED BY EMPTYING HOUSEHOLD CAN

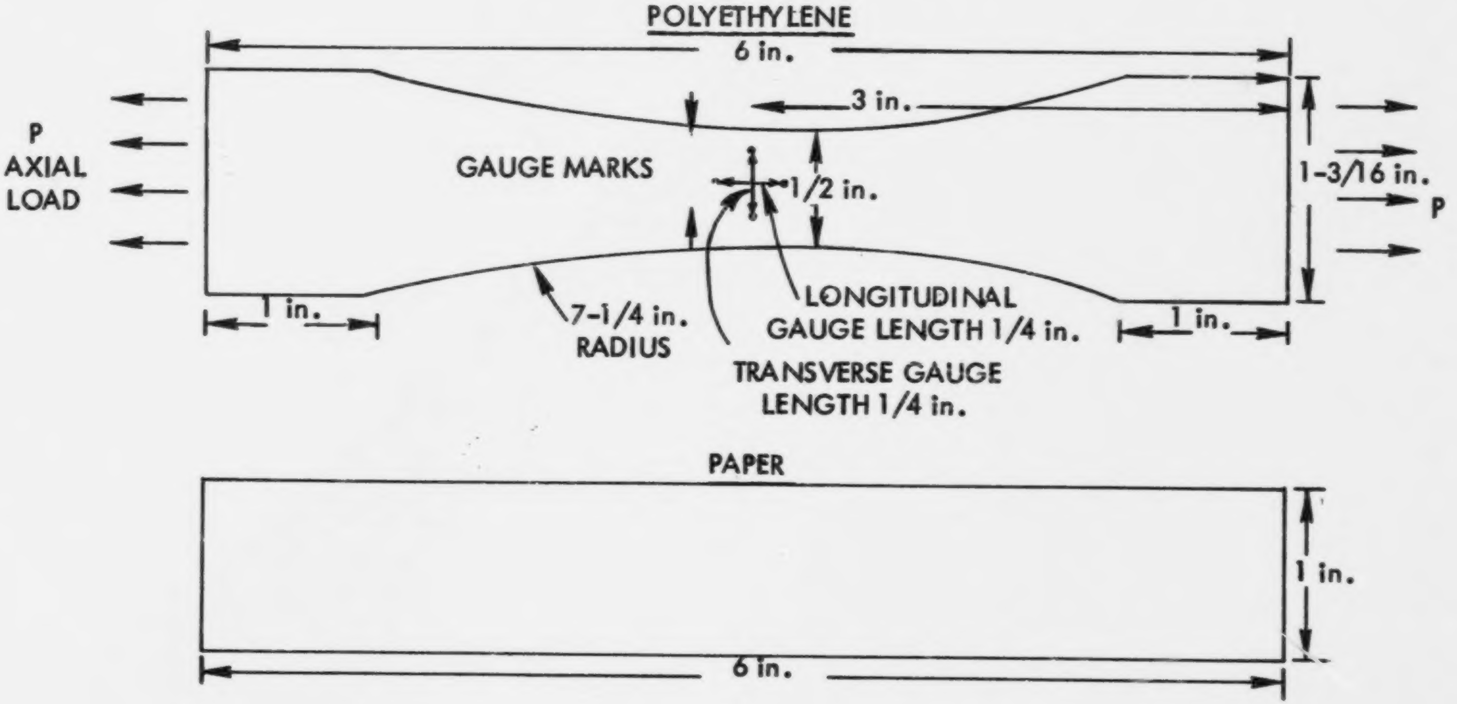
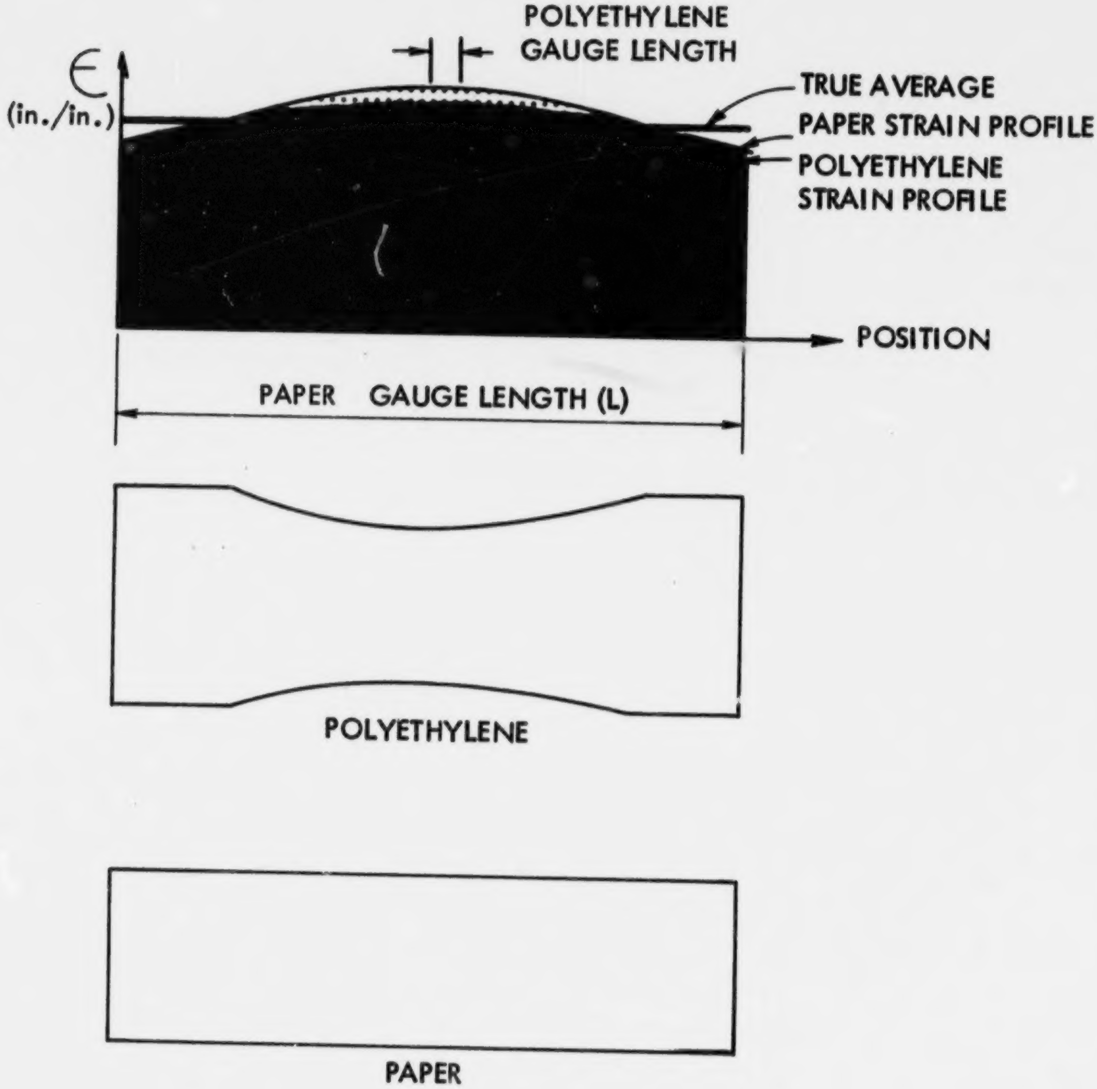

POLYETHYLENE
6 in.
3 in.
P
AXIAL
LOAD
GAUGE MARKS
1/2 in.
1-3/16 in.
P
1 in.
7-1/4 in.
RADIUS
LONGITUDINAL
GAUGE LENGTH 1/4 in.
1 in.
TRANSVERSE GAUGE
LENGTH 1/4 in.
PAPER
1 in.
6 in.

FIGURE 37

TEST SPECIMEN
DIMENSIONS

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


POLYETHYLENE
GAUGE LENGTH
∈
(in./in.)
TRUE AVERAGE
PAPER STRAIN PROFILE
POLYETHYLENE
STRAIN PROFILE
POSITION
PAPER GAUGE LENGTH (L)
POLYETHYLENE
PAPER

TEST SPECIMEN CONFIGURATIONS

FIGURE 38

DISTRIBUTION OF STRAIN

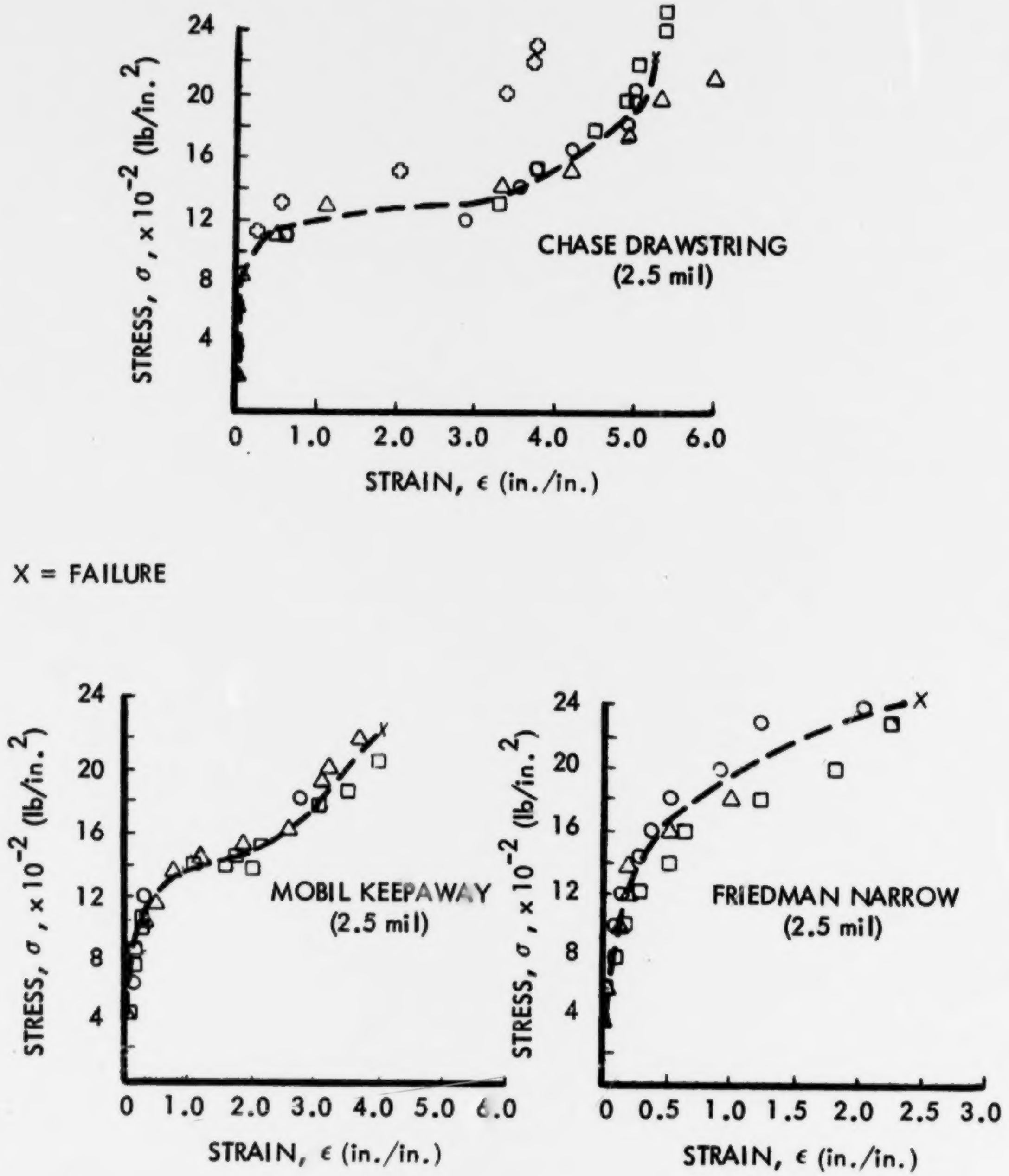


FIGURE 39

STRESS-STRAIN CURVES,
POLYETHYLENE BAG SPECIMENS

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

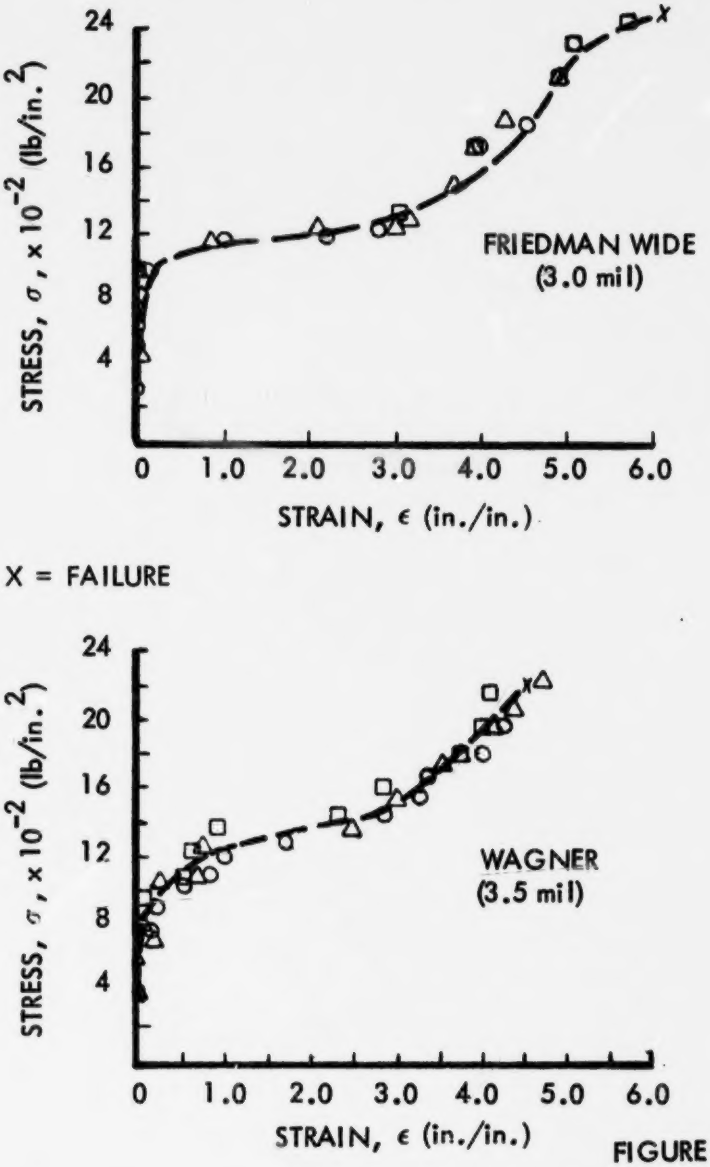
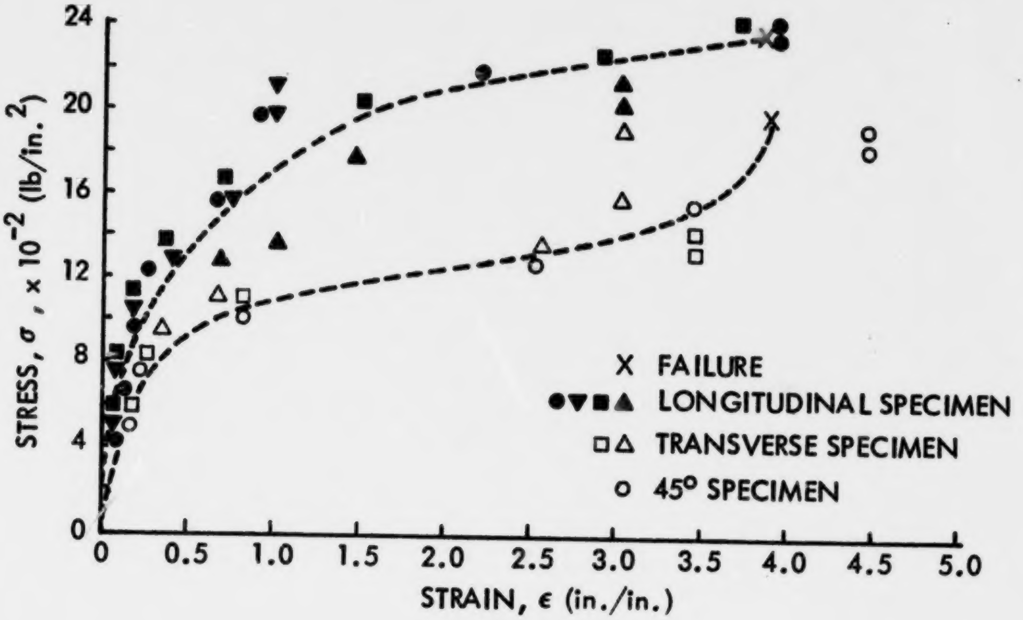
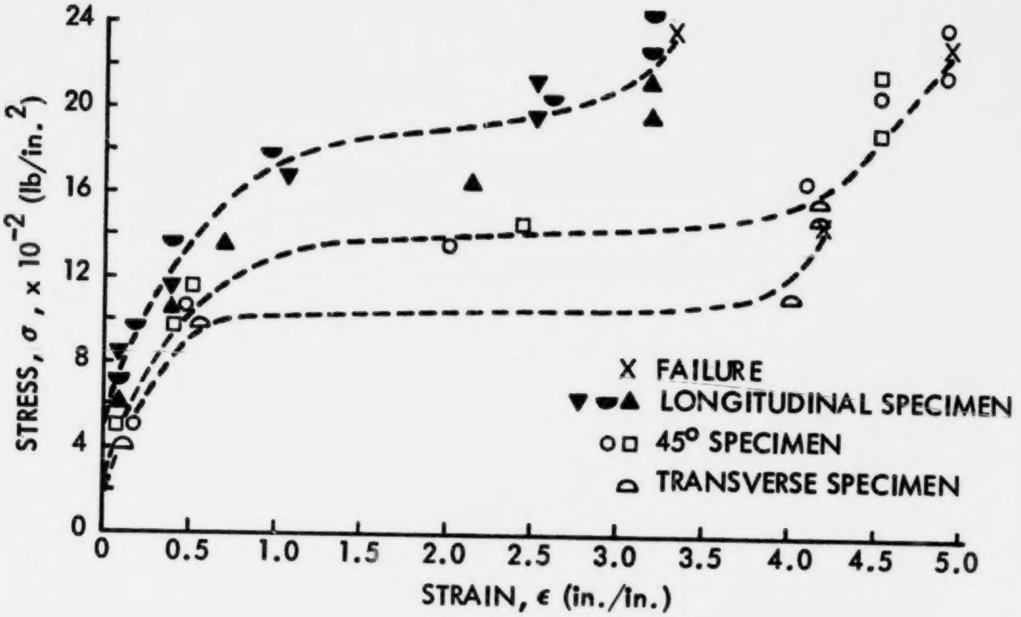


FIGURE 40

STRESS-STRAIN CURVES,
POLYETHYLENE CAN
LINER SPECIMENS



4 CU YD BIN LINER
(2.0 mil)



3 CU YD BIN LINER
(2.0 mil)

FIGURE 41

STRESS-STRAIN CURVES,
POLYETHYLENE BIN LINER SPECIMENS

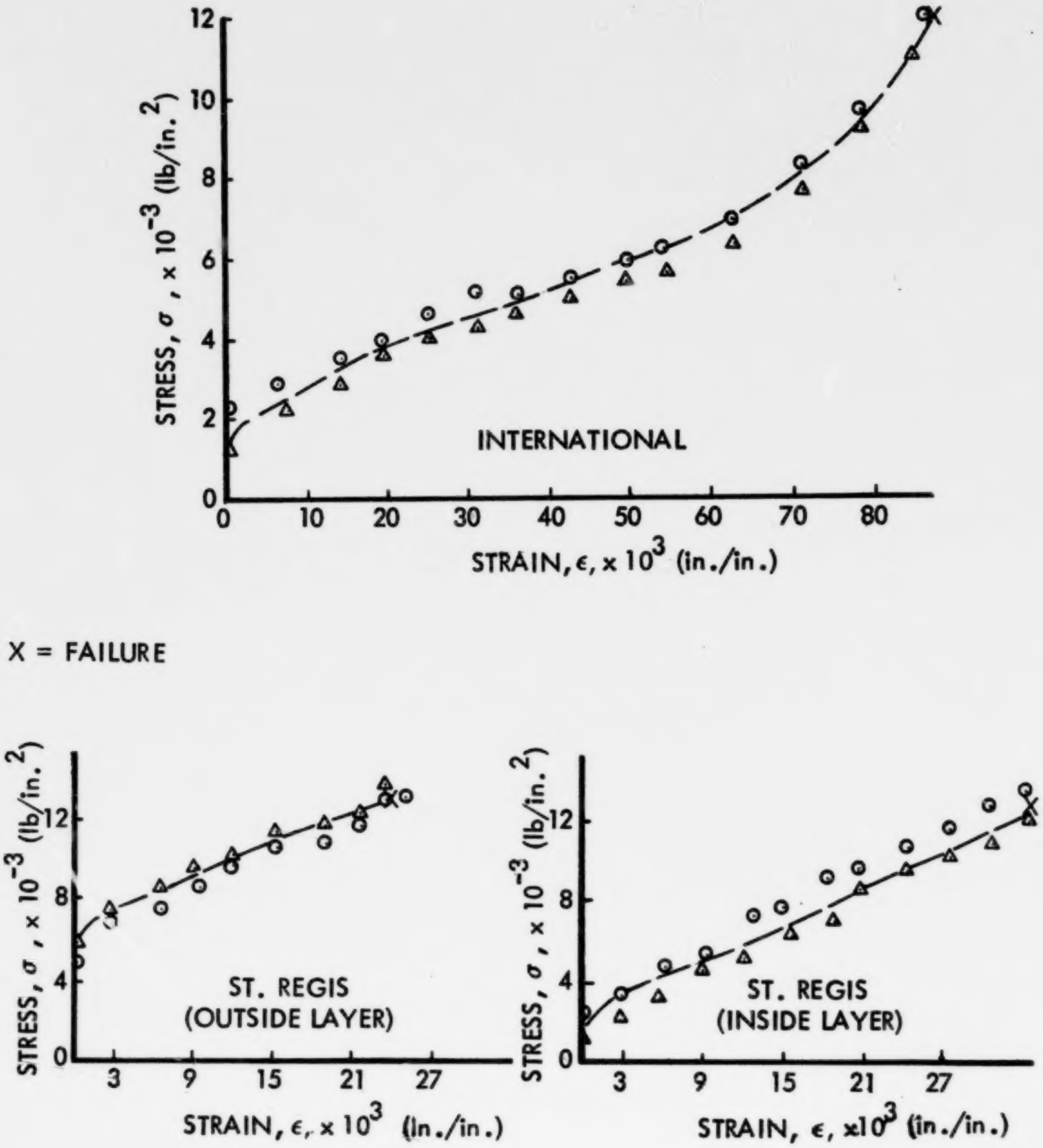
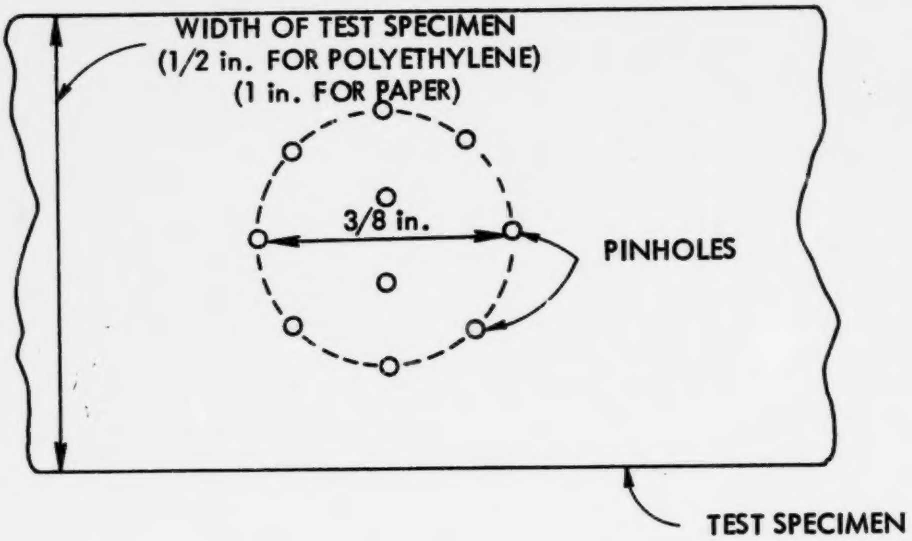


FIGURE 42

STRESS-STRAIN CURVES,
PAPER BAG SPECIMENS
LONGITUDINAL CUT

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.


WIDTH OF TEST SPECIMEN
(1/2 in. FOR POLYETHYLENE)
(1 in. FOR PAPER)
3/8 in.
PINHOLES
TEST SPECIMEN

NO SCALE

FIGURE 43

TYPICAL PINHOLE
TEST SPECIMEN

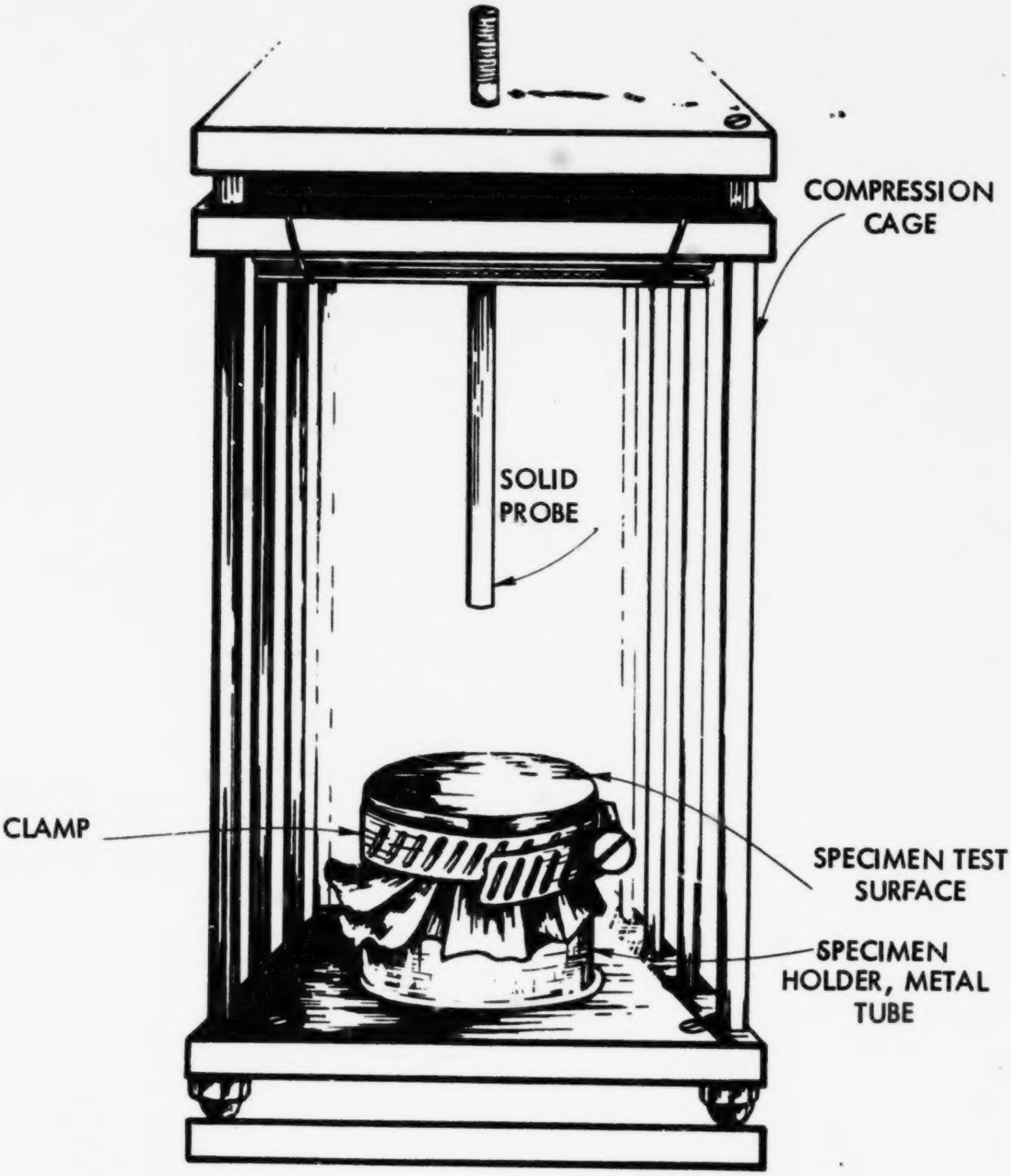

COMPRESSION CAGE
SOLID PROBE
CLAMP
SPECIMEN TEST SURFACE
SPECIMEN HOLDER, METAL TUBE

FIGURE 44

APPARATUS FOR PUNCTURE TESTS

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

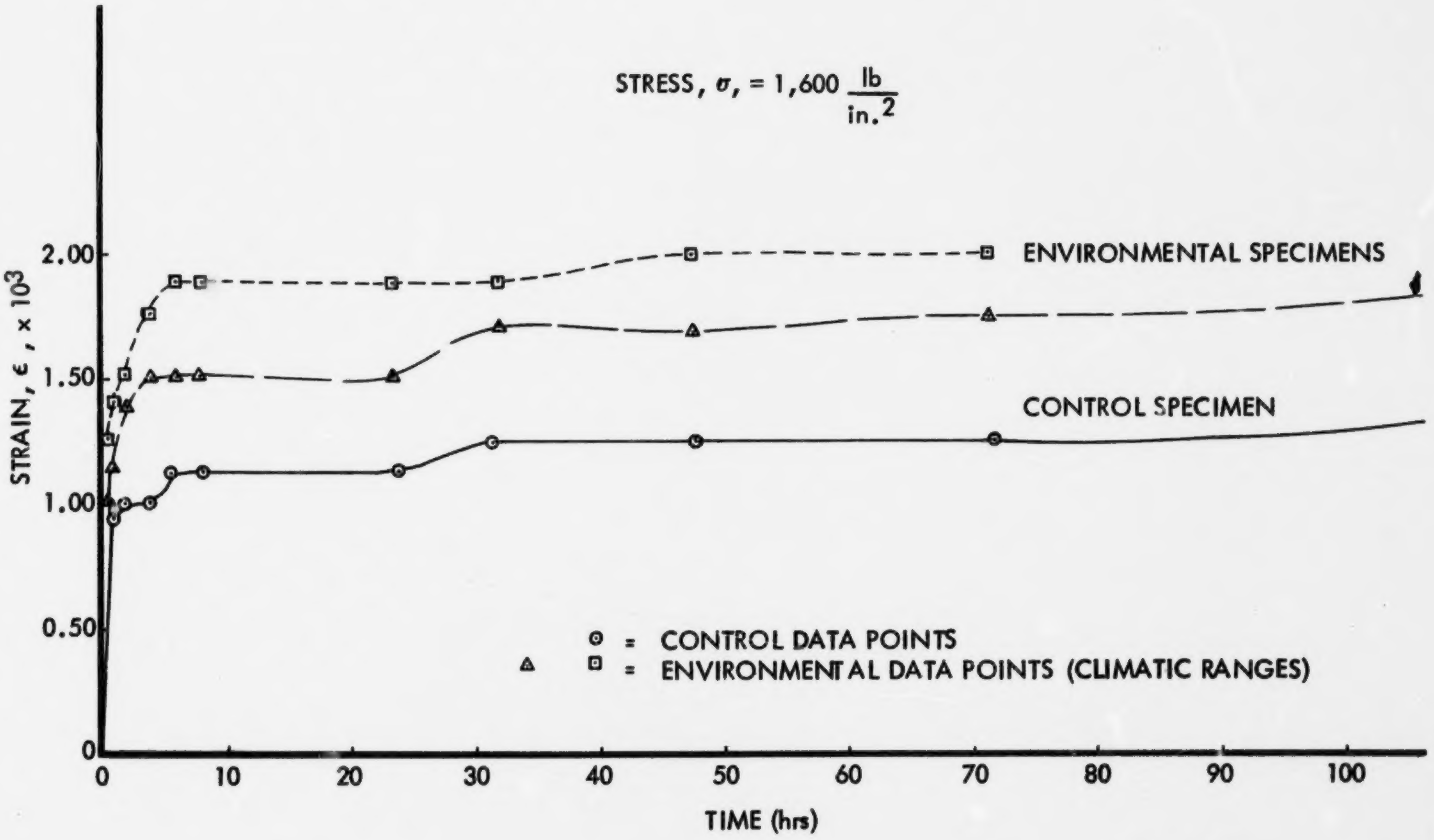


FIGURE 45

LONGITUDINAL STRAIN-TIME CURVES,
FRIEDMAN POLYETHYLENE BAG
(2.5 mil), NARROW

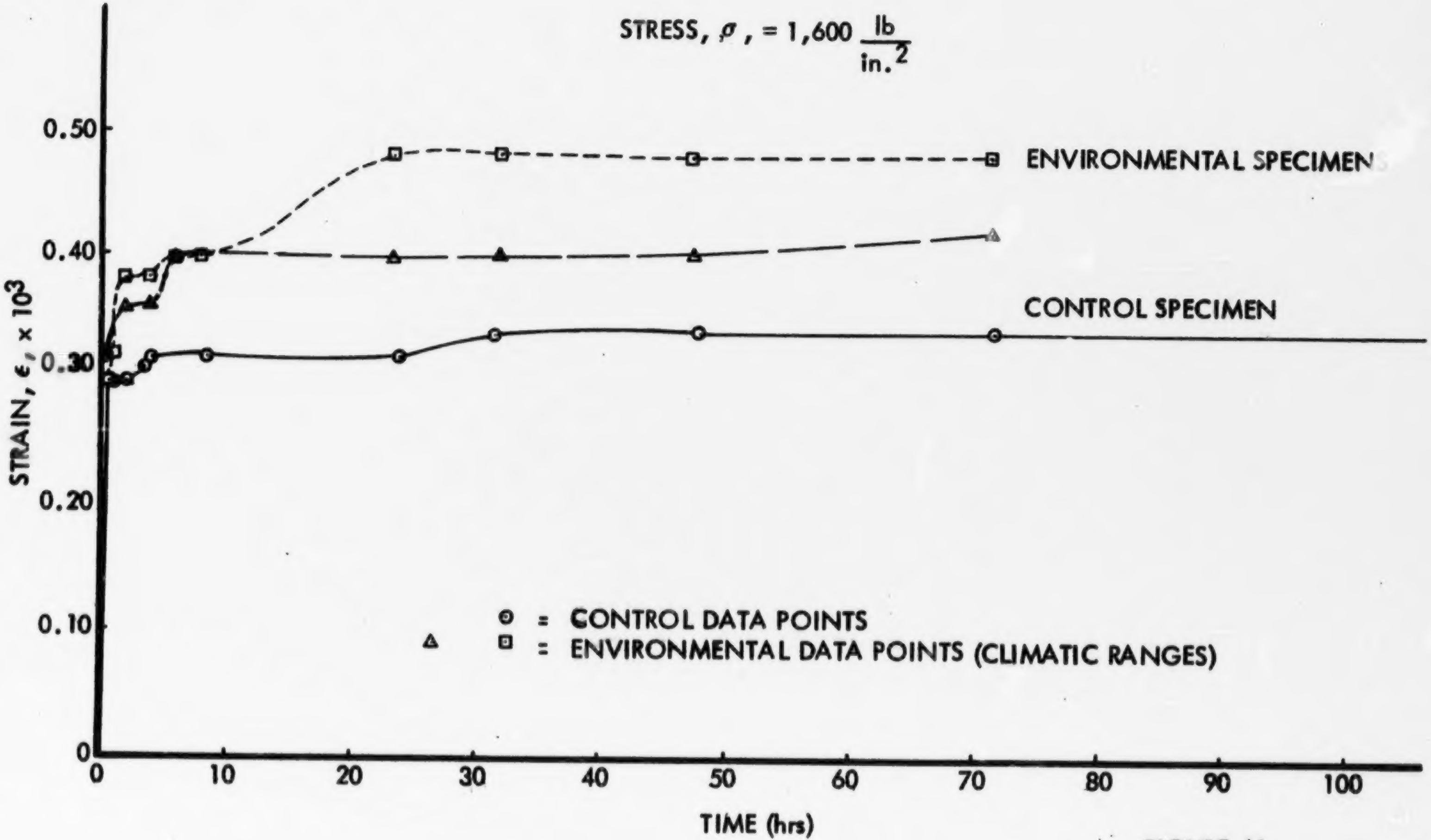


FIGURE 46

TRANSVERSE STRAIN-TIME CURVES,
FRIEDMAN POLYETHYLENE BAG
(2.5 mil), NARROW

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

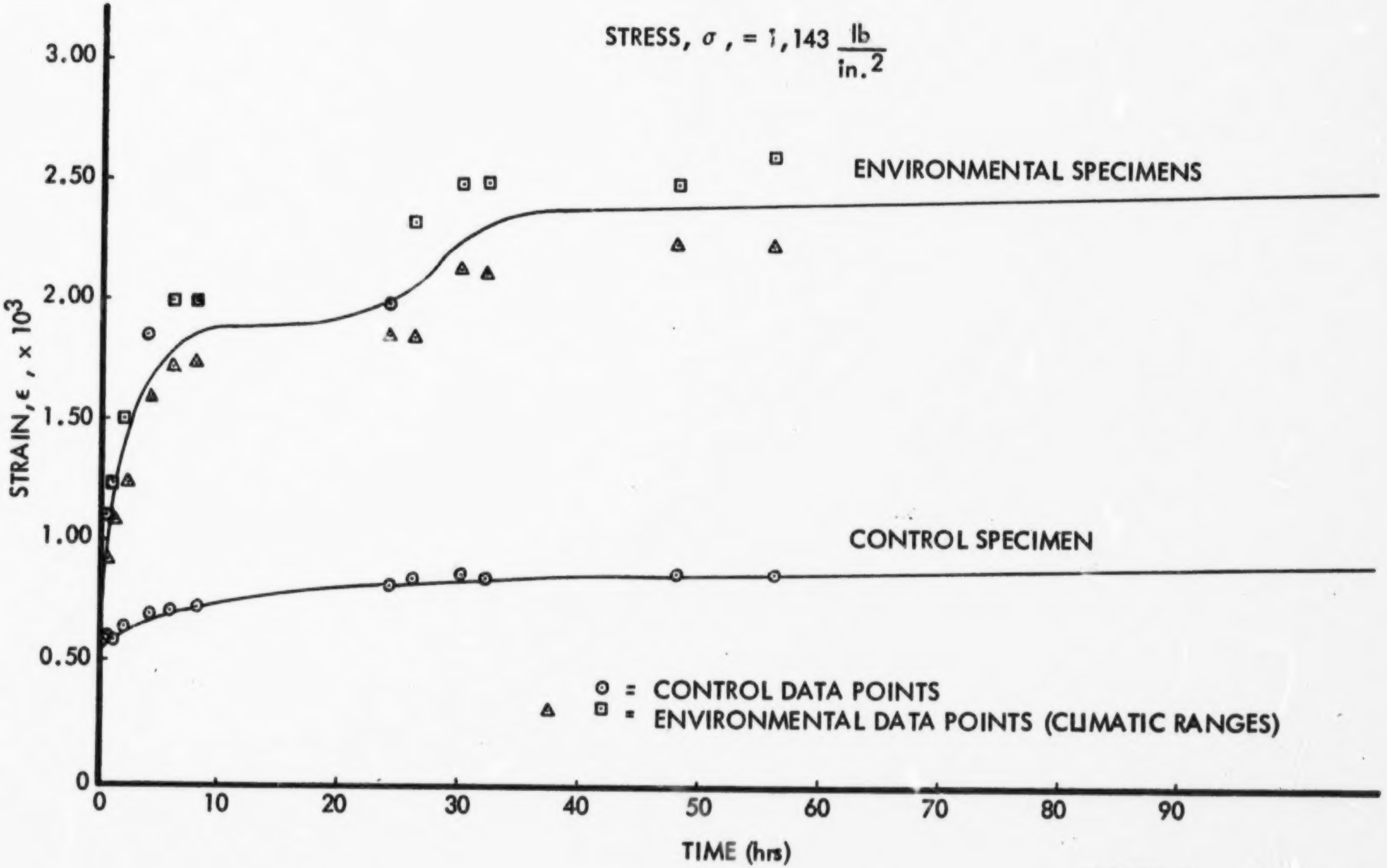
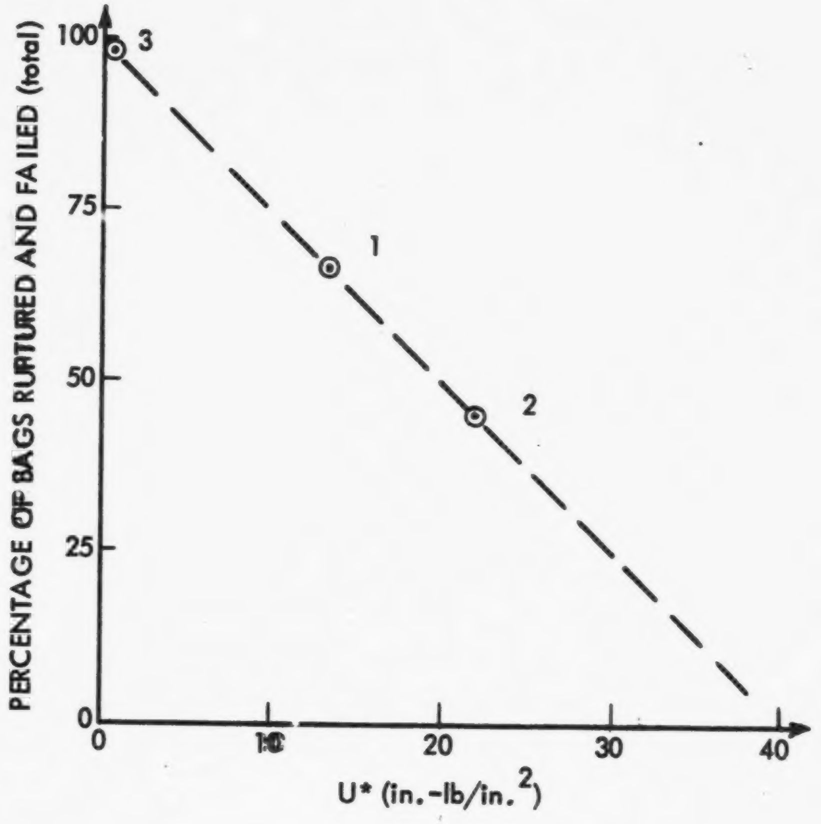


FIGURE 47

LONGITUDINAL STRAIN-TIME CURVES, WAGNER POLYETHYLENE LINER (3.5 mil)

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



Point 1. Based on combined field data for Mobil Keepaway and Friedman Narrow bags.
Point 2. Based on combined field data for Friedman Wide and Wagner liners.
Point 3. Assuming 100 percent failure occurs at zero U*.

FIGURE 48

PERCENT FAILURE OF
POLYETHYLENE BAGS VERSUS U*

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

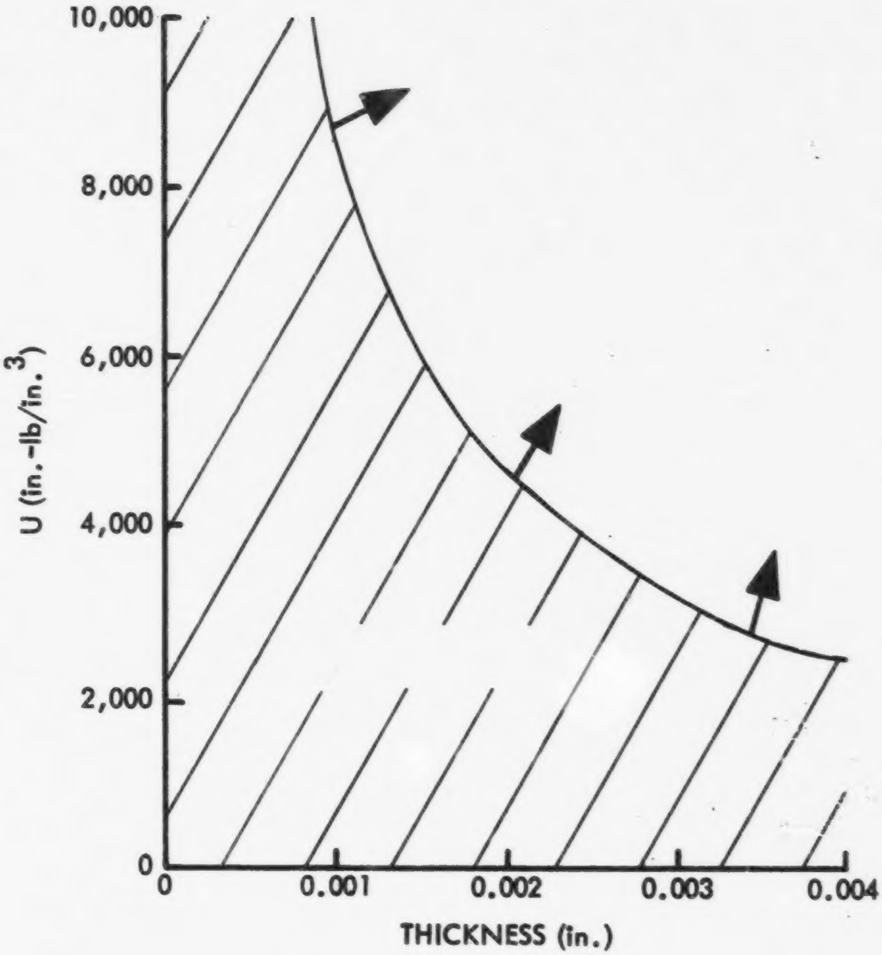


FIGURE 49

ACCEPTABLE VALUES OF U
AS A FUNCTION OF
POLYETHYLENE BAG THICKNESS
(SHADED REGION IS UNACCEPTABLE)

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

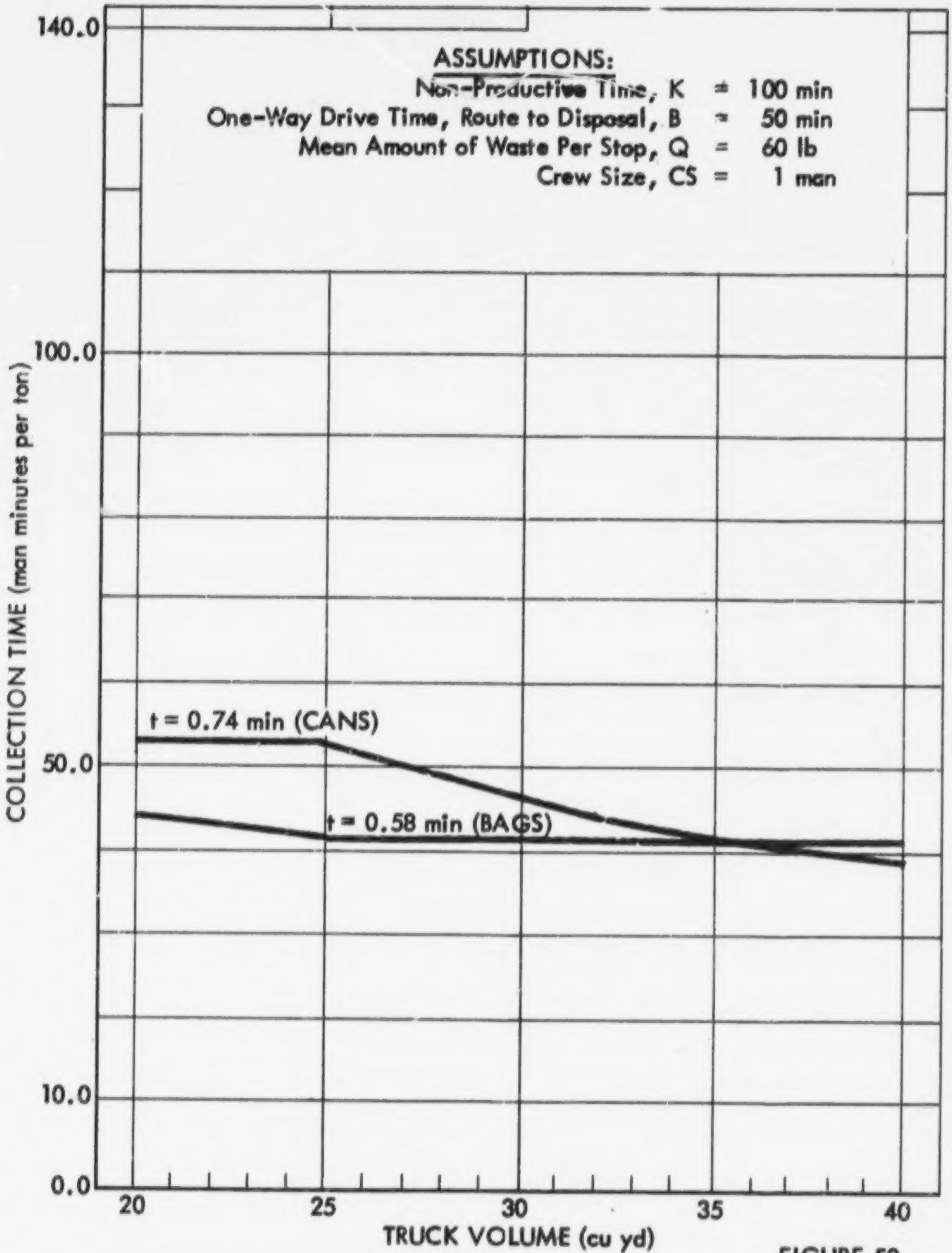
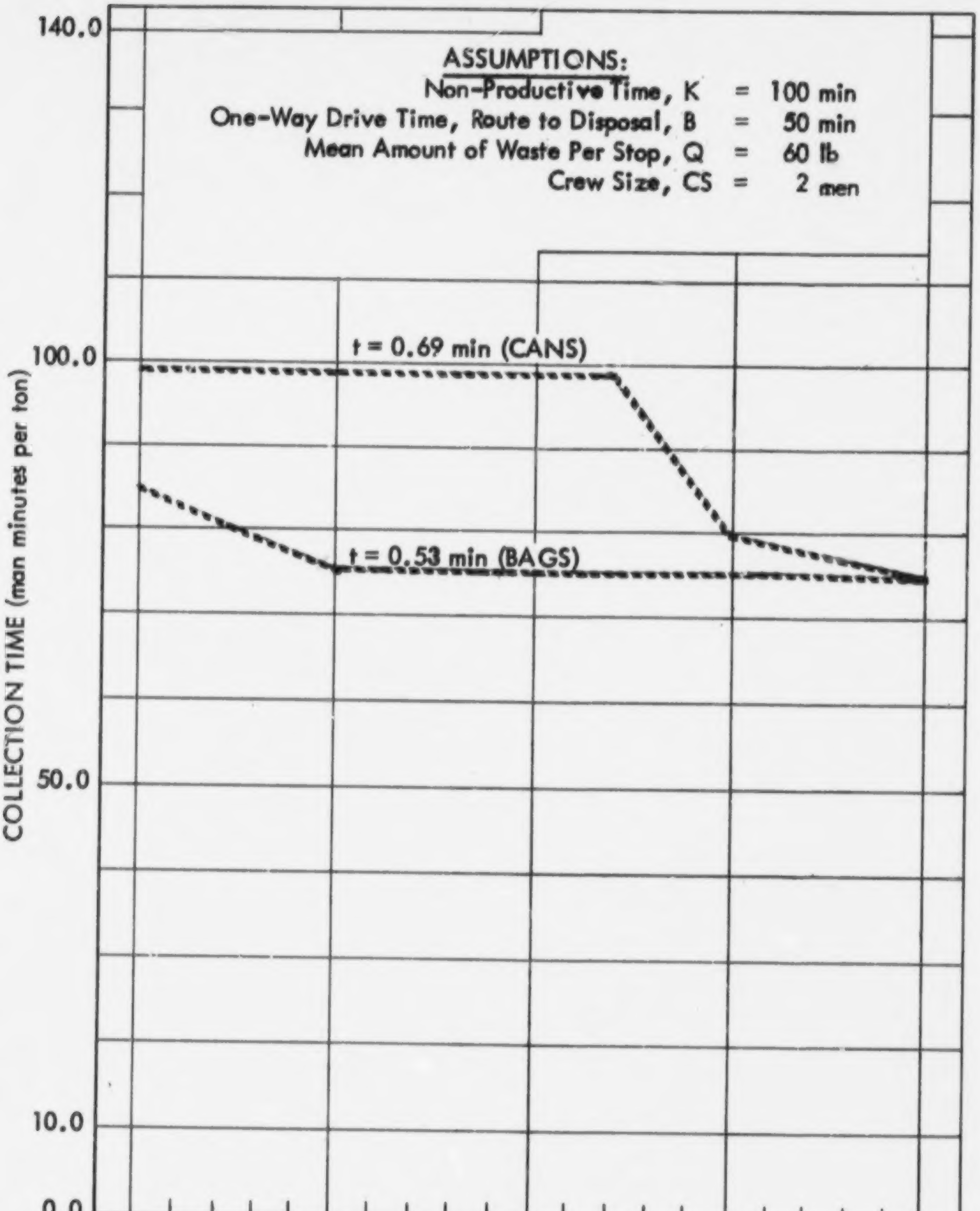


FIGURE 50

CAN-BAG COLLECTION TIMES
ONE-MAN CREW

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 51
CAN-BAG COLLECTION TIMES
TWO-MAN CREW

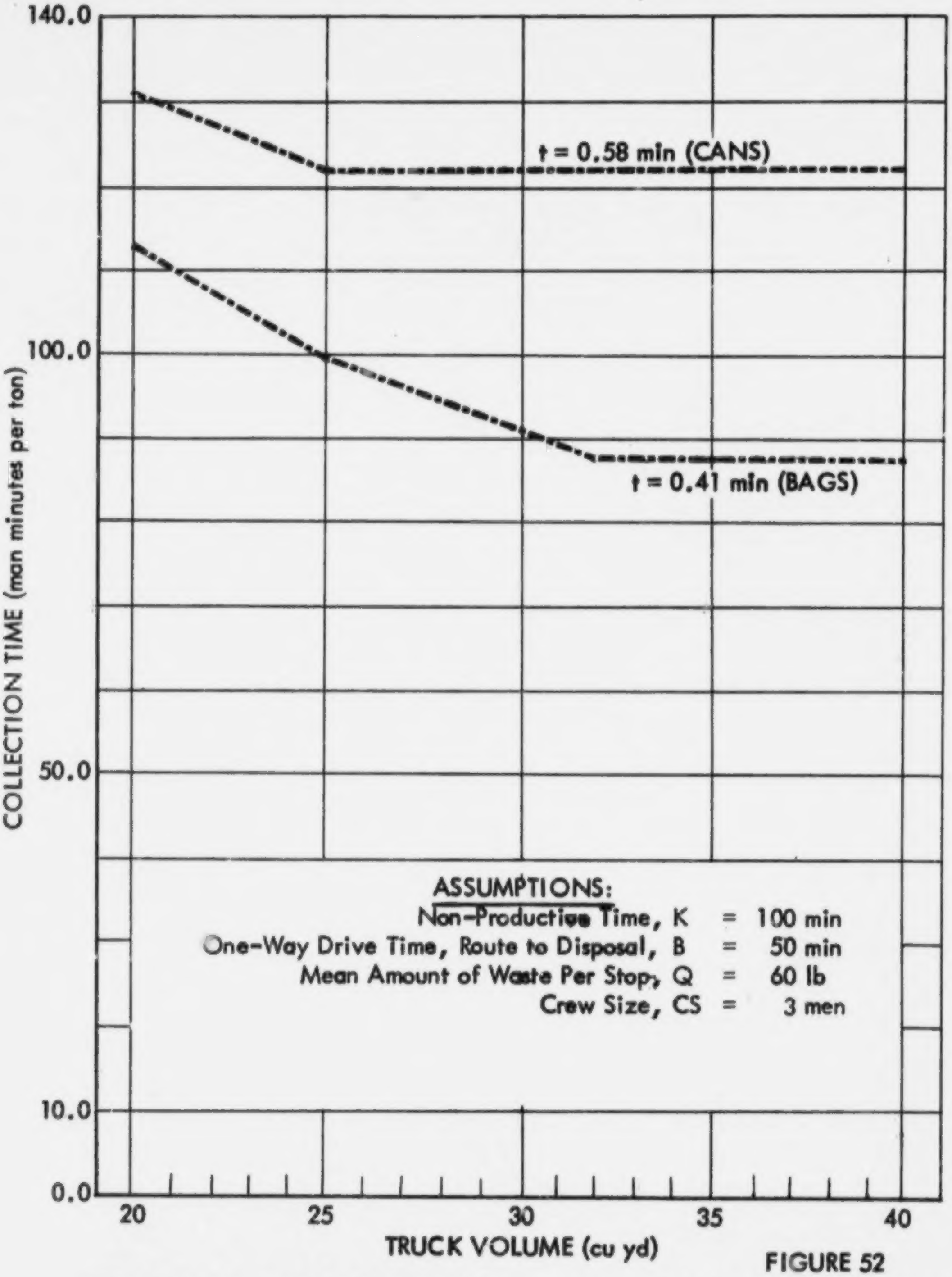


FIGURE 52
CAN-BAG COLLECTION TIMES
THREE-MAN CREW

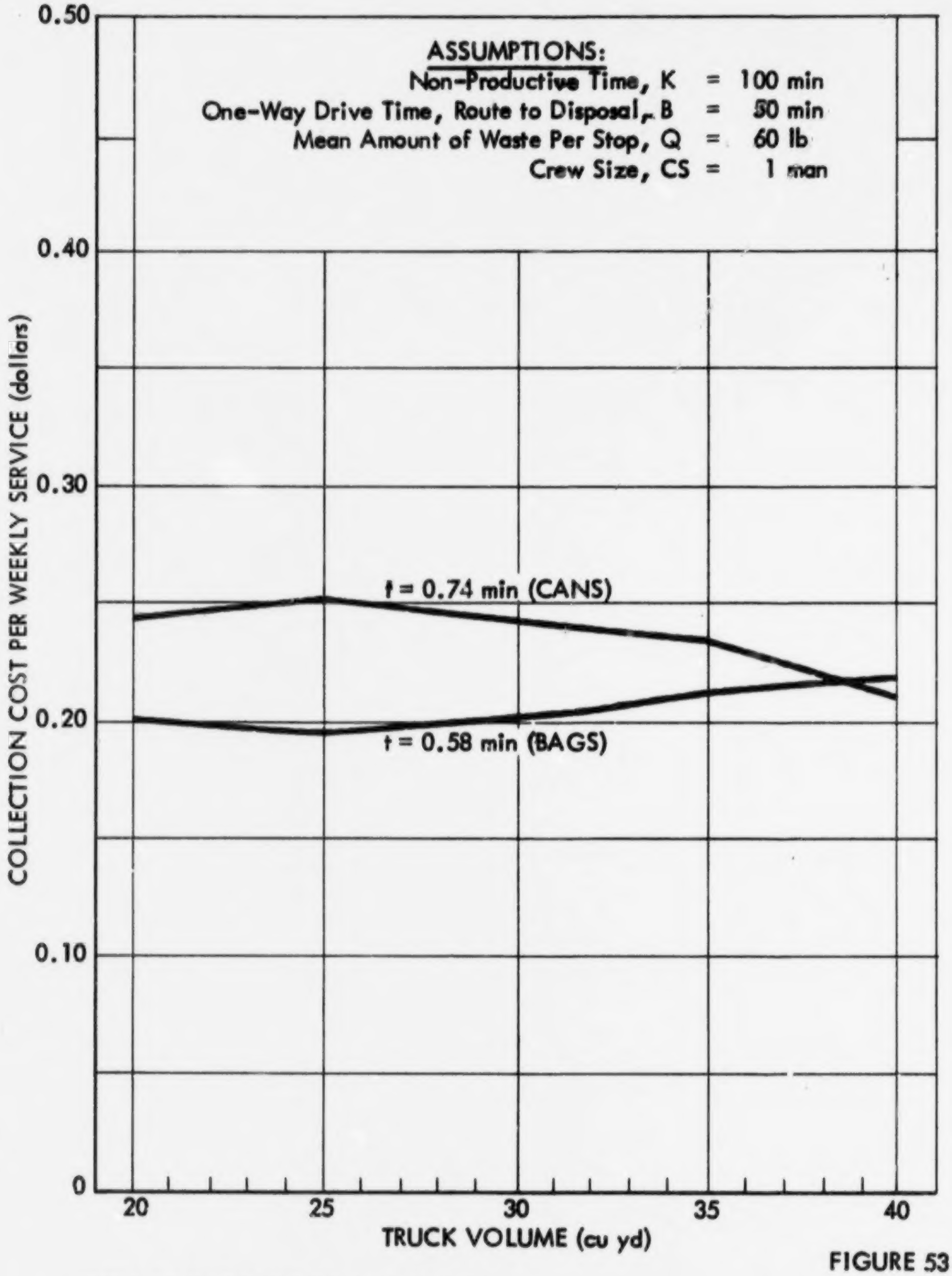


FIGURE 53
CAN-BAG COSTS
ONE-MAN CREW

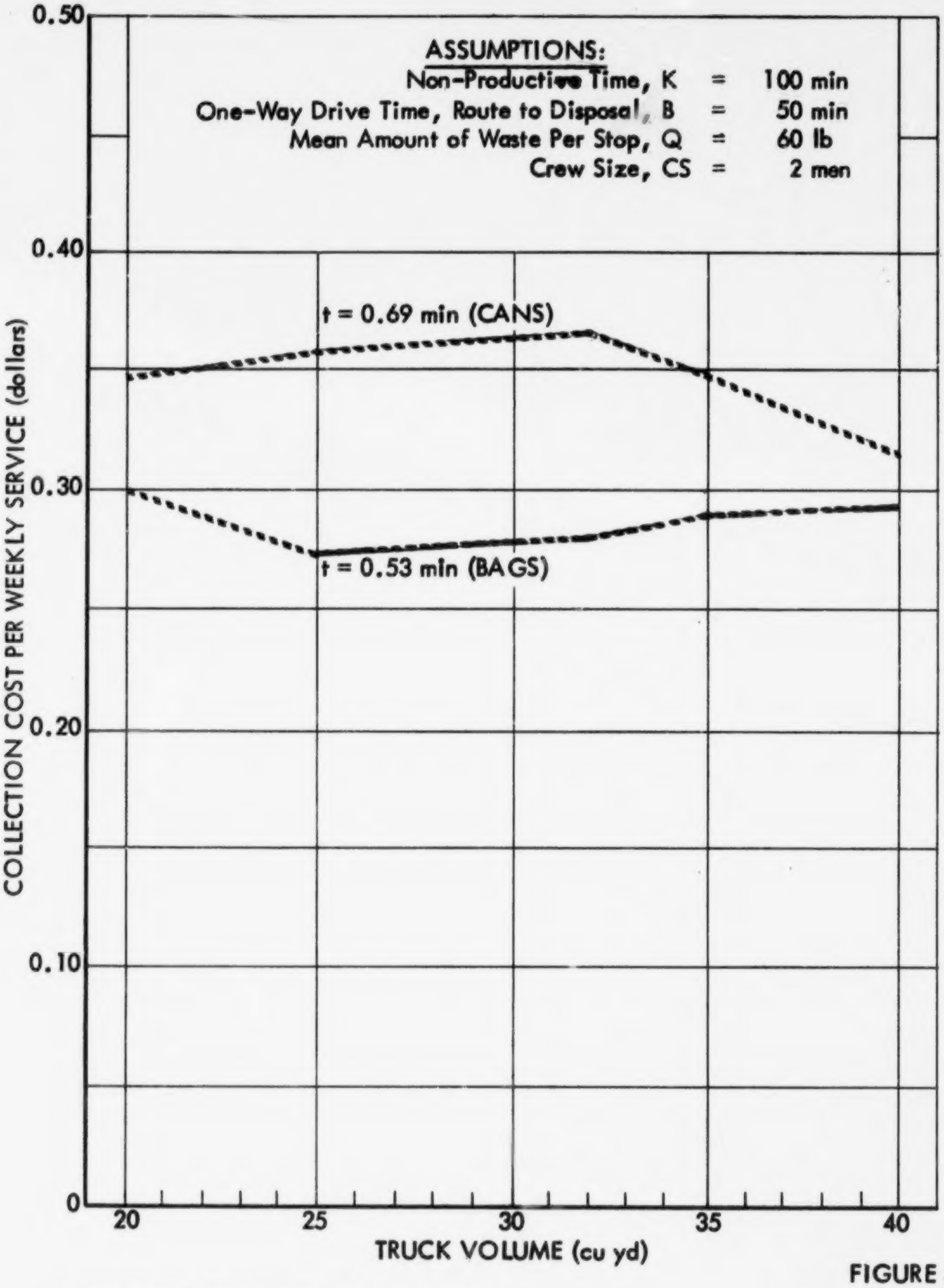
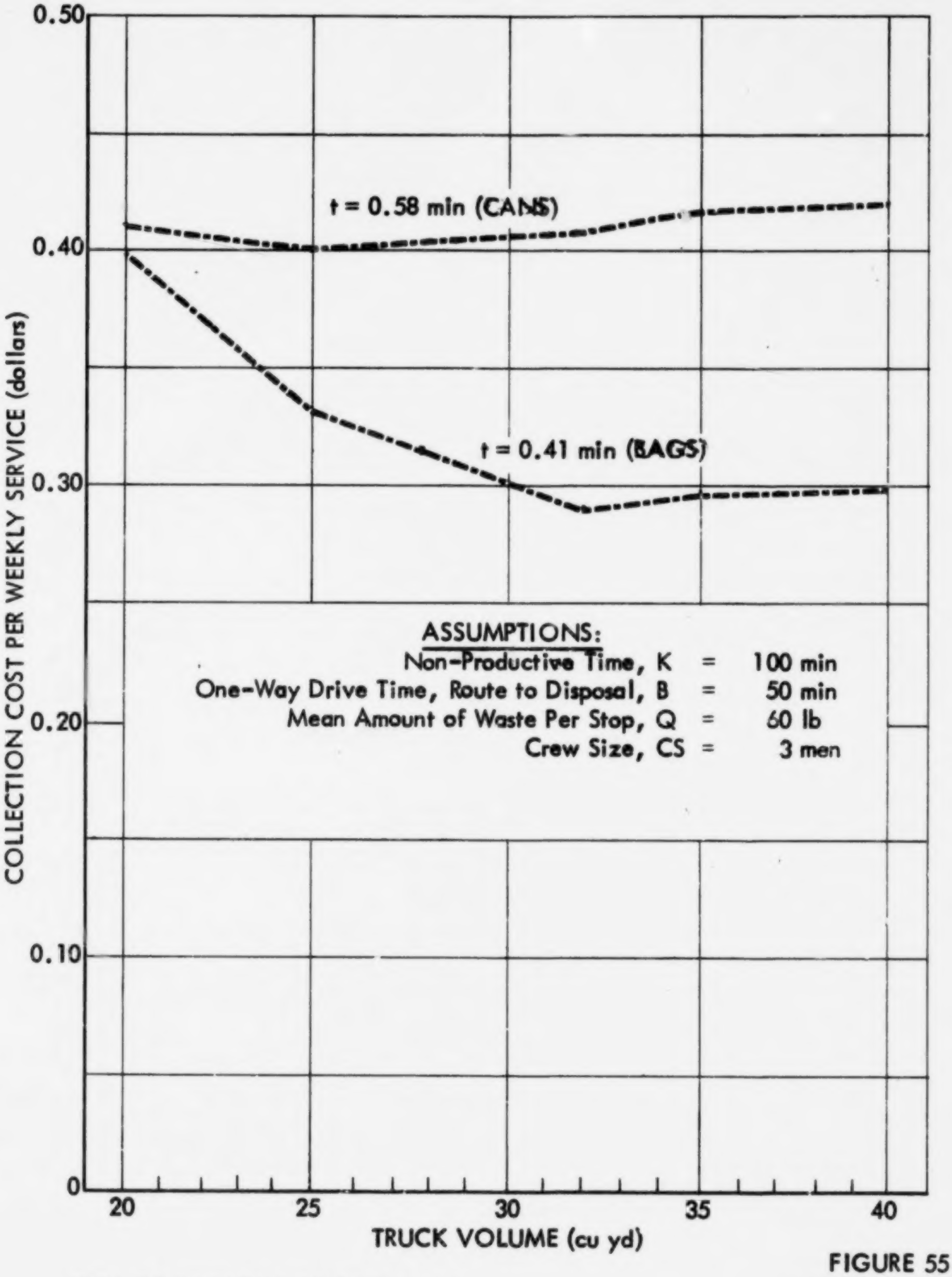


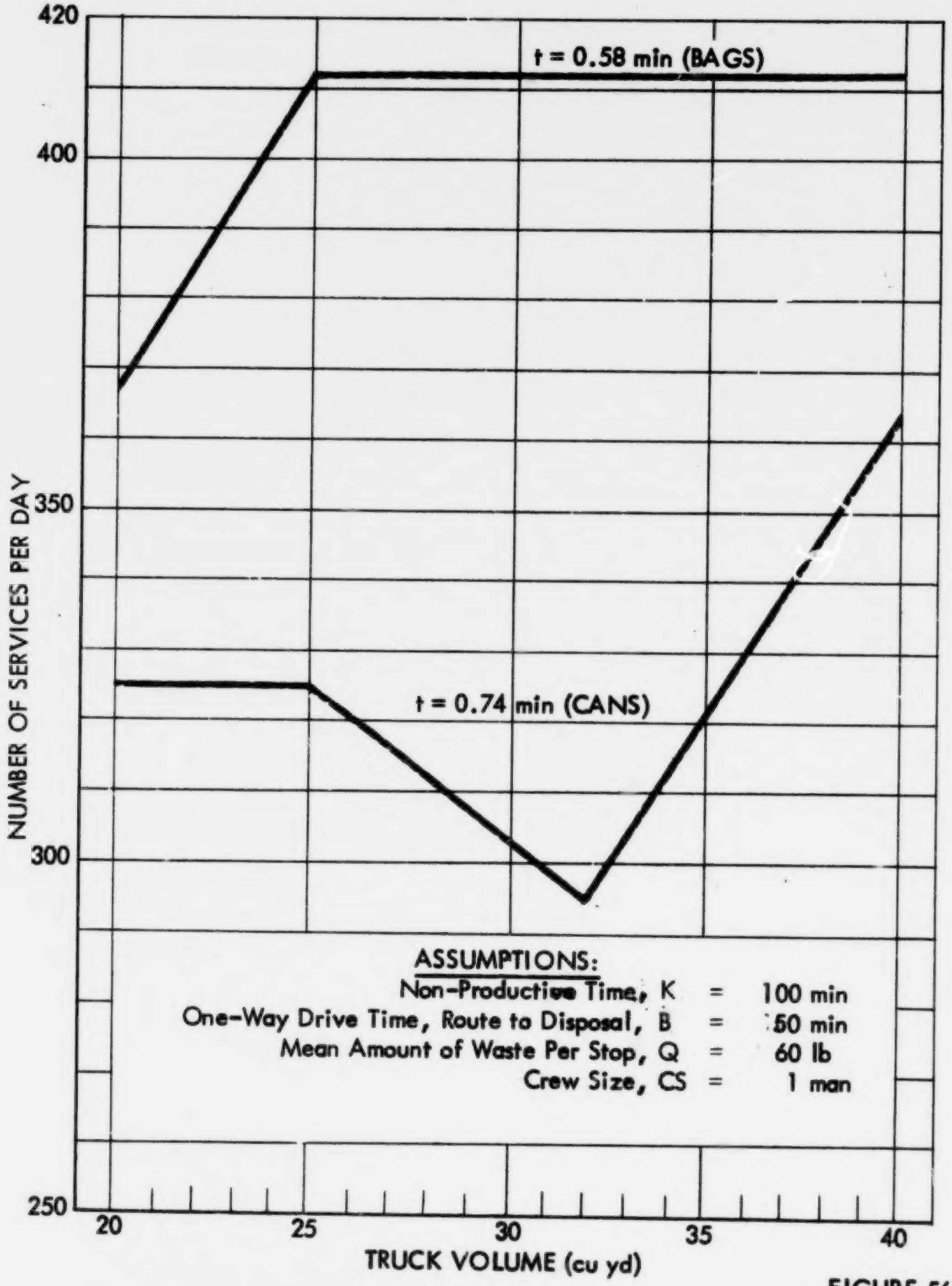
FIGURE 54
CAN-BAG COSTS
TWO-MAN CREW

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

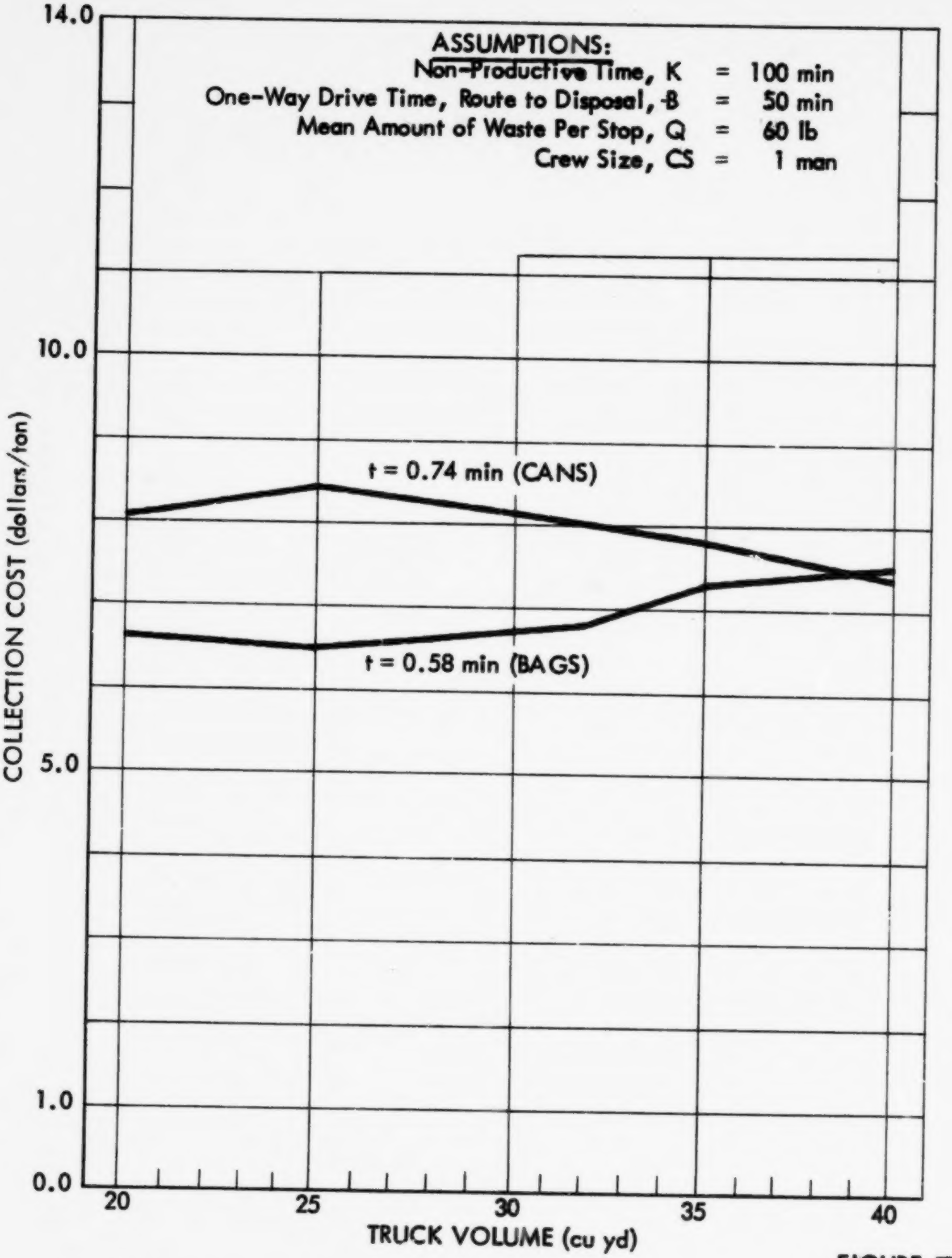
FIGURE 55
CAN-BAG COSTS
THREE-MAN CREW



ASSUMPTIONS:
Non-Productive Time, K = 100 min
One-Way Drive Time, Route to Disposal, B = 50 min
Mean Amount of Waste Per Stop, Q = 60 lb
Crew Size, CS = 1 man

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 56
CAN-BAG SERVICES
ONE-MAN CREW



CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

FIGURE 57
CAN-BAG COSTS
ONE-MAN CREW

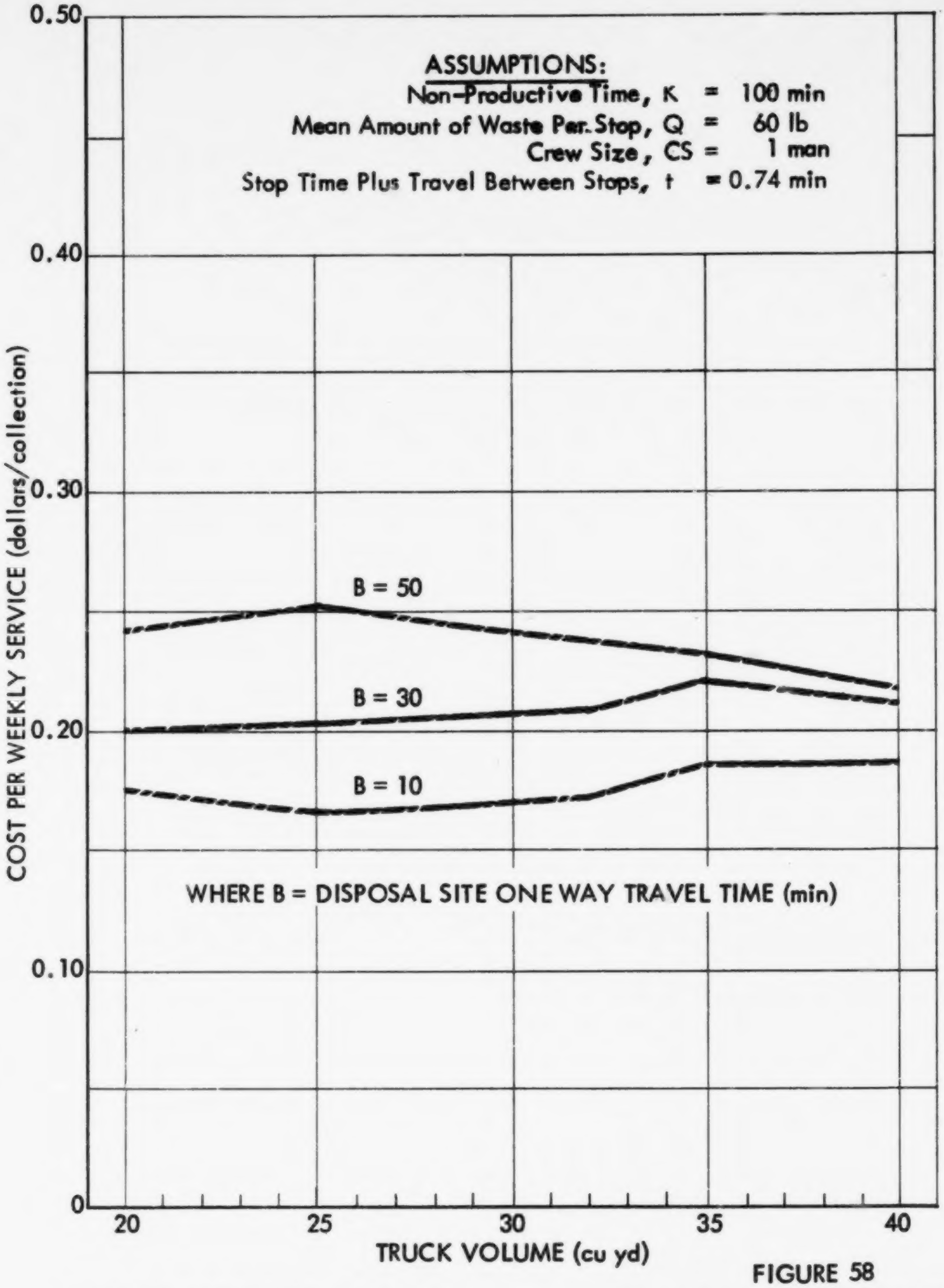


FIGURE 58

EFFECT OF DISPOSAL TRAVEL TIME
ON COSTS PER SERVICE

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

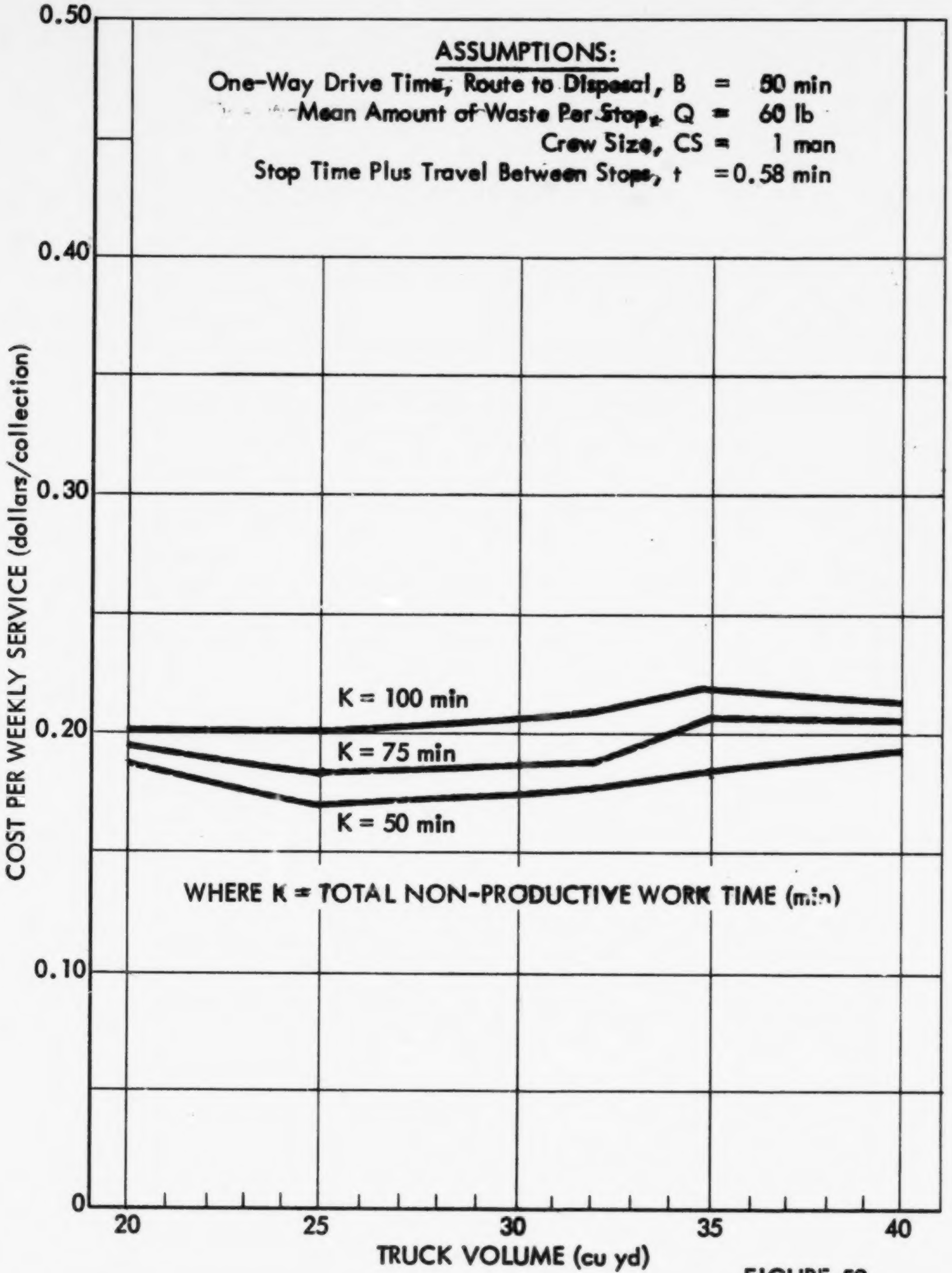
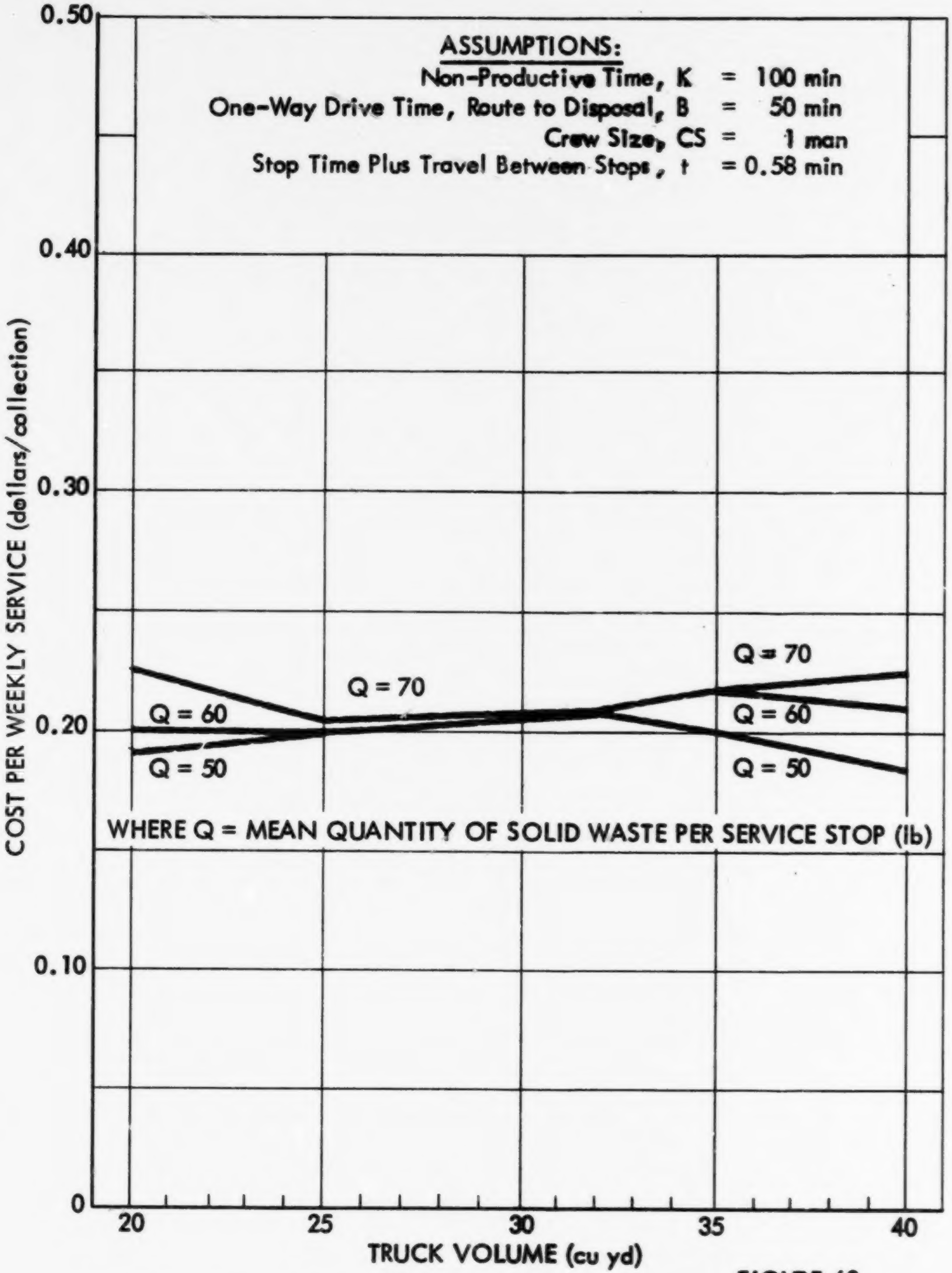


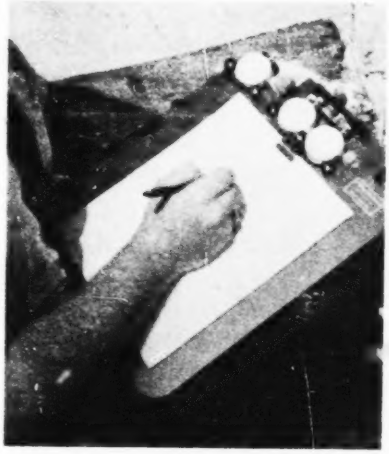
FIGURE 59

EFFECT OF NON-PRODUCTIVE WORK TIME ON COSTS PER SERVICE

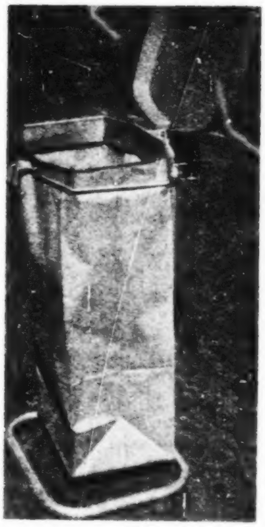


CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

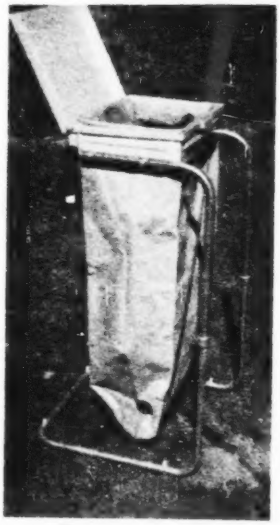
FIGURE 60
EFFECT OF MEAN QUANTITY OF
SOLID WASTE ON COSTS PER SERVICE



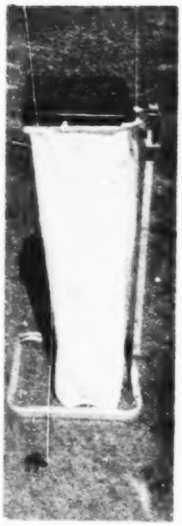
A



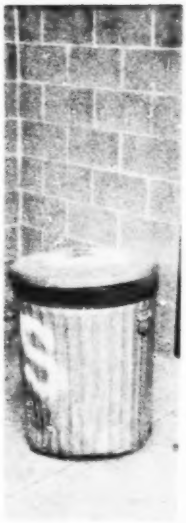
B



C



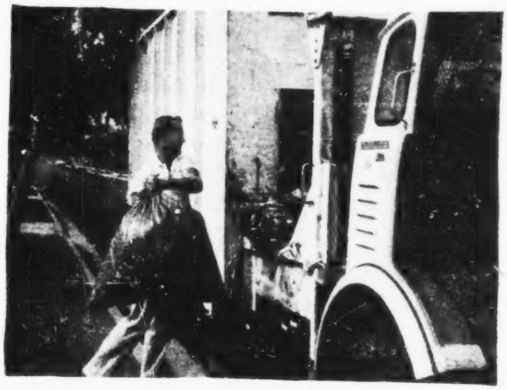
D



E

A. Time and Motion Sequential Timer Equipment.
B. St. Regis Paper Bag with St. Regis Holder.
C. International (Garbax) Bag with International Holder.
D. Mobil (Flamegard) Polyethylene Bag with Mobil Holder.
E. Mobil (Luxriliner) Polyethylene Can Liner Installed.

PLATE 1
PHOTOGRAPHS



A

B

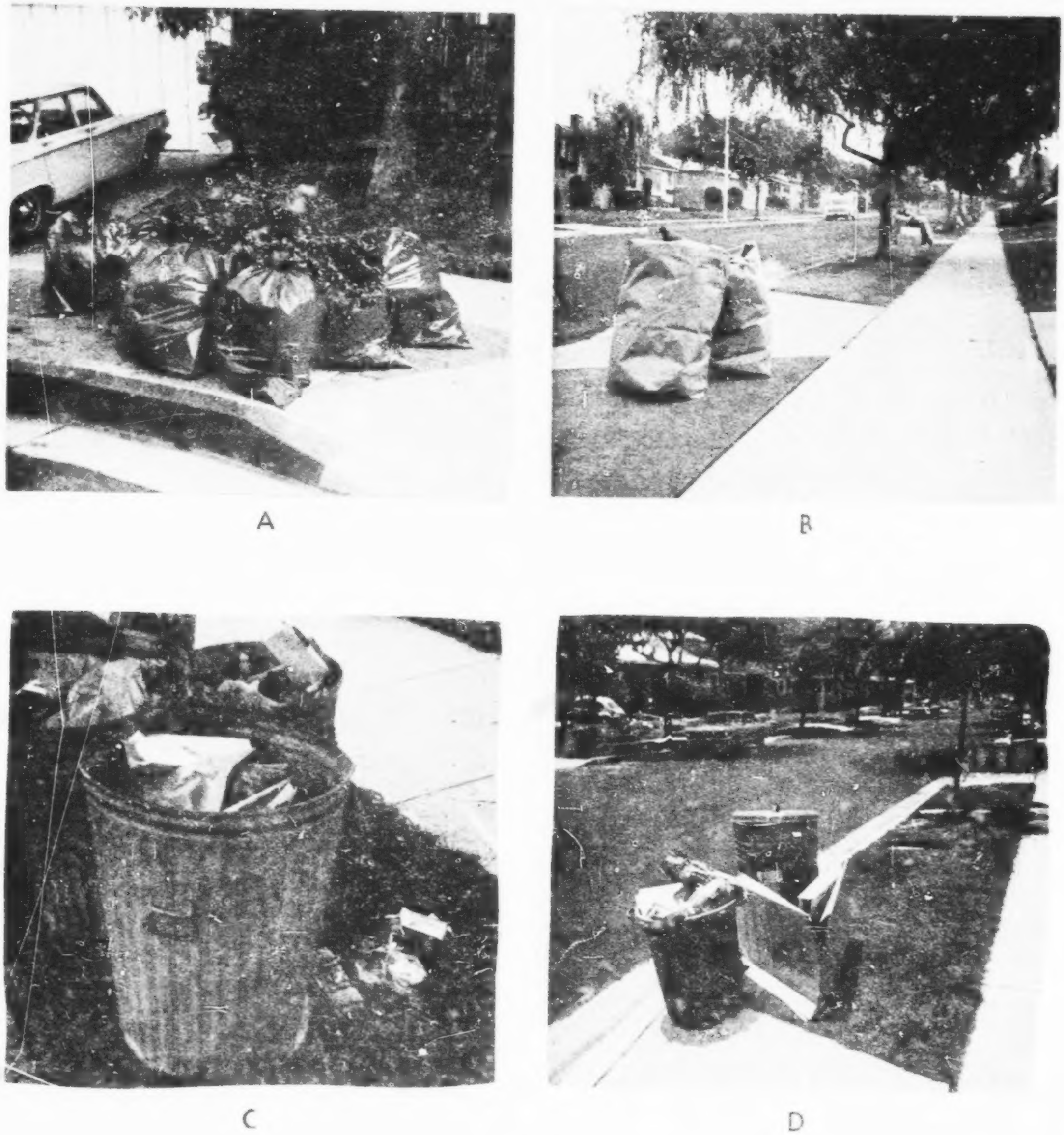
C

D

E

A. Collector Loading Polyethylene Bag by Holding Handle Provided by Closure with Paper-Covered Wire.
B. Bin with a Slipped Liner.
C. B and K Precision Sound Level Meter.
D. Typical Waste Picked Up for Litter Index.
E. St. Regis Paper Bag Rotted from Resting on Damp Ground (time period unknown).

PLATE 2
PHOTOGRAPHS



A. Closed Polyethylene Bags Ready for Collection.
B. Street with Paper Bags on Day of Collection.
C. Conventional Trash Cans.
D. Street with Cans on Day of Collection.

CITY OF INGLEWOOD/U.S.P.H.S.
RALPH STONE AND COMPANY, INC.

PLATE 3
PHOTOGRAPHS

APPENDIX A

GLOSSARY

Bag--plastic or paper bags specifically intended for containment of solid waste materials. These bags normally have a capacity greater than 20 gal.

Bag system--the bag system refers to the manufacturer's complete system for use of the bag. This may include the disposable bag and tie only in the case of a liner, or the disposable bag, tie, and a suitable permanent type holder in other instances.

Bin--solid waste container of one cubic yard, or larger, of capacity normally used in apartment houses or commercial and industrial establishments for the storage of solid waste.

Can--hard container.

Combined solid waste--household solid waste including wrapped garbage and yard trimmings.

Cost per unit capacity--C^* = relative cost; cost per unit volume of bag (or, alternatively, of appropriate cost per unit of useful capacity, or cost per unit of solid waste capacity).

Disposable container--bags.

Energy absorption--$u^* = ut$, where t = measured thickness of test specimen, u = strain energy; total maximum energy absorption capability per actual material cross sectional area.

Hard containers--rigid or semi-rigid metal, wood, or plastic containers used for the storage of solid waste.

Holder--a frame for the support of the disposable bag.

Item--any separate, individual piece of solid waste, container, bag, box, bundle, etc., placed at a collection stop.

Stop--a location where solid waste is placed for collection by the collector. The stop may contain solid waste from a single unit (such as a single family home) or from many units (such as a large apartment house).

Strain--ϵ_u = ultimate strain; strain at failure in uniaxial loading.

Strain energy--u = strain energy, or energy per unit volume up to the point of failure in uniaxial loading; this corresponds to the total area under the stress-strain curve; u is thus a measure of ability of the material to absorb energy without failure.

Stress--σ_u = ultimate stress; stress at failure in uniaxial loading; force $\div$ cross sectional area.

Unit--a place of residence for one person or family; dwelling unit.

APPENDIX B

STANDARDS FOR PAPER AND POLYETHYLENE BAGS

Two standards are in existence at present covering bags for solid waste storage; one relates to polyethylene bags and the second is at present a proposed standard for paper bags. A short summary of each is presented.

1. Polyethylene Bags.[a] The standard essentially sets out allowable material composition, material performance, bag characteristics, and bag performance.

a. Resin. Film for bags shall be manufactured from polyethylene or ethylene copolymer resin.

b. Film. Film produced from the resin specified in Item(a)shall comply with the following:

Dart impact strength at fold and seals shall not be less than 60 grams when tested in accordance with ASTM D-1709, Method A.

The nominal gauge of the film shall be 1.5 mil with point-to-point variation not to exceed ±20 percent.

NOTE: This requirement is not intended to preclude the use of nominal wall thickness in excess of 1.5 mil; however, the ±20 percent mentioned shall apply to said nominal wall thickness.

The film shall be capable of incineration under normal municipal incinerating practices. (See Incinerator Guidelines - 1969, U.S. Public Health Service.)

c. Dimensions. The bags shall have a minimum circumference of 60 in. and a minimum inner dimension of 37 in.

d. Slip Coefficient. The bags shall be readily opened by hand and shall have a slip coefficient between 0.1 and 0.25, when tested in accordance with ASTM D-1894.

e. Heat Seal. Any heat seal shall withstand a ten-minute tensile loading of 1 lb per inch of seal without failure.

---

[a] National Sanitation Foundation Standard Number 31 Relating to Polyethylene Refuse Bags (April 1970).

f. Drop Resistance. Bags shall withstand a drop of five (5) feet onto smooth concrete when filled to a total weight of thirty (30) pounds with material having a weight density of fifteen (15) pounds per cubic foot. The bag shall be securely closed with a twist tie.

g. Weight. The bags, exclusive of packaging and ties, shall have a minimum weight of 105 lb per 1,000 bags.

h. Closures. Each package of bags, intended for retail sales, shall contain an equal quantity of five (5) inch wire tie closures or their equivalent.

2. Paper Bags.[a] The proposed standard sets out minimum requirements for bag and material performance together with allowable alternate materials and fabrication.

a. Papers. Sacks shall be fabricated either wholly from non-extensible or from extensible WET STRENGTH Kraft paper, as specified, and shall be fabricated to meet the minimum paper test requirements of Table B1 or B2.

b. Adhesives. Adhesives used for seams and closures shall be water-resistant types and shall meet the requirements of the current Federal Specification UU-S-48.

c. Tape. The tape used on the ends of sewn sacks shall be 2 1/8 in. wide with a 1/8 in. minus tolerance and an unlimited plus tolerance, and shall be made from Kraft paper, non-extensible, extensible, or creeped having a basis weight of not less than 70 lb per 3,000 sq ft.

d. Thread. The stitching on the ends of sewn sacks shall be not less than 12/5 cotton needle thread and 12/4 cotton looper thread, or rayon THREAD OF EQUIVALENT STRENGTH.

e. Markings. Paper used in these sacks shall be distinctly marked for identification by longitudinal stripes spaced not less than 2 in. nor more than 10 in. on centers across the paper width, and each stripe shall be not less than 1/8 in. in width. Markings shall appear on the external surface of the sack.

f. Performance. The sack shall withstand a drop of five (5) feet onto smooth concrete when filled to a total weight of forty (40) pounds with a material having a weight density of fifteen (15) pounds per cubic foot. Sacks shall be closed by crimping, tying, or any suitable means to prevent spillage of contents during testing.

g. Physical Requirements. The minimum physical requirements are given in Tables B1 and B2.

---

[a] Proposed National Sanitation Foundation Standard for Paper Refuse Sacks.

H. Tests. Tests shall be conducted in accordance with the TAPPI standard methods listed below except as noted above, and the CURRENT Federal Specification UU-S-48.

	TAPPI[a] Standard Method
Conditioning	T 402
Tensile Breaking Strength	T 404
Basis Weight	T 410
Wet Tensile Breaking Strength[b]	T 456
Tensile Energy Absorption, Wet and Dry[b]	T 494
Water Resistance Test	UU-S-48

---

[a] Technical Association of Pulp and Paper Industry.

[b] Wet tensile strength and wet tensile energy absorption are to be determined by using one-inch width specimens that have been immersed in water for two hours at 73°F ±3.5°F.

TABLE B1

TEST REQUIREMENTS: NON-EXTENSIBLE KRAFT

Sack Construction Number[a] (non-extensible Kraft paper)	Minimum Total Sack Capacity (cu ft)	Nominal Basis Weight (lb/3,000 sq ft)	Lot Average Total Paper Test Requirements Non-Extensible Kraft Paper			
			Minimum Basis Weight (lb/3,000 sq ft)	Tensile		
				Dry		Wet[b]
				CD (lb/in.)	Total MD±CD (lb/in.)	CD (lb/in.)
4	4.5	100	95.0	34.0	95.0	9.0

[a] Sack construction number 4 corresponds with sack construction number 4 in the latest issue of National Refuse Sack Council, Inc., "Sepcification Sacks, Paper, Refuse".

[b] Wet tensile strength and wet tensile energy absorption are to be determined by using one-inch width specimens that have been immersed in water for two hours at 73°F ±3.5°F.

MD = Machine Direction
CD = Cross Direction

TABLE B2

TEST REQUIREMENTS: EXTENSIBLE KRAFT

			Lot Average Total Paper Test Requirements			
			Extensible Kraft Paper			
				Tensile Energy Absorption		
				Dry		Wet
Sack Construction Number[a] (extensible Kraft paper)	Minimum Total Sack Capacity (cu ft)	Nominal Basis Weight (lb/3,000 sq ft)	Minimum Basis Weight (lb/3,000 sq ft)	CD (ft-lb/ sq ft)	Total MD±CD (ft-lb/ sq ft)	CD (ft-lb/ sq ft)
4-X	4.5	90	95.5	9.3	30.8	2.7

[a] Sack construction number 4-X corresponds with sack construction number 4-X in the latest issue of National Refuse Sack Council, Inc., "Specification Sacks, Paper, Refuse".

[b] Wet tensile strength and wet tensile energy absorption are to be determined by using one-inch width specimens that have been immersed in water for two hours at 73°F ±3.5°F.

MD = Machine Direction
CD = Cross Direction

APPENDIX C

1. SPECIFICATIONS FOR BAG AND HOLDER PURCHASES

Subject: Request for Bids - Supplying Refuse Bags for Pilot Studies in the City of Inglewood, California

Gentlemen:

We are ready to solicit bids from interested firms for the manufacture of a limited number of plastic and paper bags for use in the pilot study activities. Both plastic and paper bags will be tested under actual field conditions for a period of six months.

The attached specification is included to define requirements for bags to be supplied. Your bid should be based on the manufacture and delivery of the specified number of plastic or paper bags F.O.B. the City of Inglewood corporation yard located at 444 N. Eucalyptus, Inglewood, California. A delivery date on or before April 10, 1969 is required.

Public relations is considered an important aspect of the study and the City wishes to promote voluntary use of the bags by the resident to the maximum degree possible. The prospective bidder is requested to submit as a part of his bid an indication of the support the firm is willing to commit during the eight month test phase in terms of personnel, billboards, local newspaper, radio and television advertising to assist the City of Inglewood in promoting the use of bags on a voluntary basis. Of particular importance will be the appearance of firm personnel before service and citizen groups, presentation of promotion films and special cooperation with local merchants in advertising and saturation marketing of bags.

Deadline for receipt of bids is 11:00 a.m. on March 10, 1969. No bid will be considered after this date. Please indicate your delivery schedule.

Additionally, in order for the City to evaluate economic relationships, please indicate the following along with your regular bid.

A. Unit cost for car-load quantities of bags to meet the attached specification.

B. Added unit cost for single uniform bag color.

C. Added unit cost for one-color printing on the bag.

Thank you for your continuing interest in the City of Inglewood bagging study.

Very truly yours,

William F. Farnam
Director of Public Works

WF:RS:sm

Attachments

APPENDIX C

2. SPECIFICATION #68-30 FOR PAPER BAGS FOR SOLID WASTE

I. SCOPE

This specification covers the minimum requirements for new and unused paper refuse bags for containment of residential refuse in the City of Inglewood, California.

II. MATERIAL REQUIREMENTS

A. Paper. Paper refuse bags shall be fabricated wholly from wet-strength extensible or wet-strength flat Kraft paper.

B. Adhesives. Adhesives used for seams and closures shall be water-resistant types and shall meet the requirements of Federal Specification UU-S-48D, paragraph 3.1.2.

C. Tape. Unless otherwise specified, the tape used on sewn ends of bags shall be 2 1/3 in. wide (1/8 in. minus tolerance and unlimited plus tolerance), and shall be made from wet-strength (extensible) Kraft paper having a basis[a] weight of not less than 70 lb.

D. Thread. The stitching on the ends of sewn bags shall be not less than 12/5 cotton needle thread and 12/4 cotton looper thread, or other thread of equivalent strength.

III. PHYSICAL REQUIREMENTS

A. Paper. The specified values for the paper test properties listed in Table I are minimum satisfactory values for lot averages, and are applicable to the total bag. Tensile Energy Absorption shall be in accordance with Technical Association of Pulp and Paper Industry (TAPPI) Standard T 494.

---

[a] Basis weight refers to the weight of 3,000 sq ft of single-ply or a ream of 500 sheets of 24 in. x 36 in. size paper (Ref. ASTM Standards, Part 15, April 1965).

B. Bag Dimensions.

Option 1.	Group A	Minimum	Quantity
	Capacity	30 gal	Approximately 17,500
	Face Width	15 in.	
	Gusset Width	11 5/8 in.	

Option 2.	Group B	Minimum	Quantity
	Capacity	30 gal	Approximately 17,500
	Face Width	17 in.	
	Gusset Width	10 in.	

C. End closure on bags shall be either taped and sewn or closed with the use of adhesives.

D. Two plys of paper shall be used in the bag construction; the total basis weight of which shall meet or exceed the specified weight and test properties of Table I. A single-ply bag will not be acceptable.

TABLE I[a]

Non-Extensible Kraft Paper

Nominal Basis Weight (lb)* (24 x 36) 500 sheets	Minimum Basis Weight (lb)* (24 x 36) 500 sheets	Tensile Dry CD (lb/in. width)	Tensile Total MD+CD (lb/in. width)	Tensile Wet CD (lb/in. width)
100	95.0	34.0	95.0	9.0

Extensible Kraft Paper

Nominal Basis Weight (lb)* (24 x 36) 500 sheets	Minimum Basis Weight (lb)* (24 x 36) 500 sheets	Tensile Energy Absorption Dry CD (lb/in. width)	Tensile Energy Absorption Total MD+CD (lb/in. width)	Tensile Energy Absorption Wet CD (lb/in. width)
90	85.5	9.3	30.8	2.7

* Total - 2 plys.

---

[a] Proposed standards for paper bags. See Appendix B, Standards for Paper and Polyethylene Bags.

IV. BAG TESTING

The City reserves the right to perform sampling, testing, and evaluation of bags supplied for conformance to specifications. The lot shipment may be rejected and returned to the bag manufacturer, freight collect, should the City determine that the shipment does not meet specifications herein.

A. Lot Definition. For the purpose of this specification, the lot shall consist of all paper refuse bags delivered at one time but shall not be less than 10,000 bags.

B. Sack Dimension Requirements. The sample to be used for checking for dimensional requirements shall consist of 20 individual bags selected randomly from the lot from at least 10 separate bales. Lots shall be regarded as satisfactory with regard to the absence of dimensional defects if no more than one bag in the 20 bag sample fails to conform with dimensional requirements.

The sampling and inspection procedures for dimensions are based on an acceptable quality level of 2.5 and an inspection level of S-2 as provided in Military Standard 105 "Sampling Procedures and Tables for Inspection by Attributes". The sample unit is one bag.

C. Tests. Sixteen bags shall be randomly selected from the lot. Each bag shall be from a separate bale. Two test specimens for each paper test property specified shall be taken from each ply of each bag. The lot shall be considered satisfactory if the averages of the tests on the sixteen bags conform with the requirements of Table I. The tests shall be conducted in accordance with the TAPPI standard methods listed below, except as noted above.

	TAPPI Standard Method
Conditioning	T 402
Tensile Breaking Strength	T 404
Basis Weight	T 410
Wet Tensile Breaking Strength	T 456
Tensile Energy Absorption, Wet and Dry	T 494

Wet tensile energy absorption is to be determined by using one-inch width specimens that have been immersed in water for two hours at 73°F ±3.5°F.

V. BAG CLOSURE

Indicate current firm activity, results and status in developing a suitable closure for the paper bag. Supply samples and estimated costs, if available.

VI. PREPARATION FOR DELIVERY

Fifty (50) bags shall be packed per unit and fastened securely.

APPENDIX C

3. BIDDER'S PROPOSAL FOR SPECIFICATION #68-30

Date____________________

After having carefully examined the specifications for paper bags for refuse, the undersigned (bidder) hereby proposes the following prices, to wit:

OPTION #1

Approximately 17,500 paper bags, Group A (according to specification #68-30) $____________________

State additional cost for printing $____________________

State additional cost for colored bags, per Inglewood selection $____________________

OPTION #2

Approximately 17,500 paper bags, Group B (according to specification #68-30) $____________________

State additional cost for printing $____________________

State additional cost for colored bags, per Inglewood selection $____________________

COMPANY____

BY____

ADDRESS____

____________________________ PHONE____________________

APPENDIX C

4. SPECIFICATION #68-31 FOR PLASTIC BAGS FOR SOLID WASTE

I. SCOPE

This specification covers the minimum requirements for new and unused plastic refuse bags for containment of residential refuse in the City of Inglewood, California.

II. MATERIAL REQUIREMENTS

A. Material used in manufacture shall be of the polyethylene chemical class, thermoplastic resin.

B. Unless specified elsewhere within these specifications, provisions and requirements of Federal Specification L-P-378b, dated February 6, 1967, as applied to Type II - High Impact Polyethylene, shall govern the manufacture and properties of the plastic bags.

The following polyethylene resin materials, or their equivalent, are acceptable for bag manufacture:

DuPont Alathon 2646
Union Carbide DFD-4143
Union Carbide DFD-4200
Mobile Chemical MKC

Equivalent polyethylene resin materials may be used by the bidder. A specification sheet describing the properties of the material should be submitted with the bid. Minimum requirements for selected properties are tabulated in Table I.

TABLE I

Property	Minimum Value	
	2.5 mil	3.5 mil
Impact Resistance	165 gm/cm^2	225 gm/cm^2
Tensile Strength		
Machine Direction	1,700 psi	1,700 psi
Transverse Direction	1,200 psi	1,200 psi
Ultimate Elongation		
Machine Direction	225%	225%
Transverse Direction	350%	350%

Bag Testing. The City reserves the right to perform sampling, testing, and evaluation of bags supplied for conformance to specification. The lot shipment may be rejected and returned to the bag manufacturer, freight collect, should the City determine that the shipment does not meet the specifications herein.

III. PHYSICAL REQUIREMENTS

A. Bag Dimensions.

	Group A	Group B
Tube Circumference (in.)	70	54
Tube Length (in.)	44	36
Wall Thickness (in.)	.0035	.0025
Quantity (approximate)	15,000	20,000

Maximum tolerance on tube circumference and length are ± 1/2 in. Tolerance on wall thickness is ±20%.

B. Manufacture. Bags shall be extruded in a continuous tube without a longitudinal seam. A gussetted bag may be submitted but is not required.

C. Bag bottom closures shall be watertight and have greater tensile strength (nominal) than the wall material. Minimum 1/8 in. weld seam width will be required.

D. Opacity. The contents of the bag should not be clearly visible. Samples of bag material should be supplied by the bidder for City inspection of level of opacity. There should be no color rub-off.

E. Top closures for each bag shall be provided.

F. Packaging. Bags should be securely packaged 50 to a carton.

G. Animal Repellent. Indicate on your bid the availability and cost of a chemical additive, to be incorporated into the bag material, for repelling animal attacks.

APPENDIX C

5. BIDDER'S PROPOSAL FOR SPECIFICATION #68-31

Date ____________________

After having carefully examined the specifications for plastic bags for refuse, the undersigned (bidder) hereby proposes the following prices, to wit:

OPTION #1

Approximately 15,000 plastic bags, Group A (according to specification #68-31)	$
State additional cost for printing	$
State additional cost for colored bags, per Inglewood selection	$

OPTION #2

Approximately 20,000 plastic bags, Group B (according to specification #68-31)	$
State additional cost for printing	$
State additional cost for colored bags, per Inglewood selection	$

COMPANY ____________________

BY ____________________

ADDRESS ____________________

____________________ PHONE ____________________

APPENDIX C

6. SPECIFICATION #68-32 FOR HOLDERS FOR SOLID WASTE BAGS

I. SCOPE

This specification covers the requirements for new and unused holders for refuse bags.

II. MATERIAL REQUIREMENTS

Group A (approximately 250)

Westvaco Model H-16 Circular Holder plus Model ST-43 Pipe Stand
Hudson Tidy Sack Tubular Model TM-1
International Paper Garbax Model A

Group B (approximately 250)

St. Regis Refuse Sack Holder, Model PM-40 with Pipe Stand

Group C (approximately 50)

Mobil Model PL9-1302

Prices should be based on delivery F.O.B. the City of Inglewood corporation yard, located at 444 N. Eucalyptus, Inglewood, California. A delivery date on or before April 10, 1969 is required. A bid on one or more groups is acceptable.

Firms are requested to submit bids under each of the following alternatives:

Alternate A. City purchases and retains ownership of bag holders purchased.

Alternate B. City rents the holders on a monthly basis for a period of 9 months with the firm retaining ownership.

APPENDIX C

7. BIDDER'S PROPOSAL FOR SPECIFICATION #68-32

Date____________________

After having carefully examined the specifications for refuse bag holders, the undersigned (bidder) hereby proposes the following prices, to wit:

OPTION #1

Approximately 250 refuse bag holders, Group A
(according to specification #68-32) $____________________

OPTION #2

Approximately 250 refuse bag holders, Group B
(according to specification #68-32) $____________________

OPTION #3

Approximately 50 refuse bag holders, Group C
(according to specification #68-32) $____________________

COMPANY____

BY____

ADDRESS____

______________________________ PHONE____________________

APPENDIX D

LIST OF PROSPECTIVE BIDDERS

1. **Plastic Bags**

a. Mr. Von Frodsham
Lemons Disposal
Mohawk Western Plastics, Inc.
7959 E. Imperial Highway
Downey, California 90242

b. Mr. Carl Timmons
Sales Representative
Monsanto Company
P.O. Box 3790
Anaheim, California 92803

c. Bradley's Plastic Bags
9130 Firestone Boulevard
Downey, California 90241

d. Rapco Plastics, Inc.
P.O. Box 659
612 E. McKinney
Denton, Texas 76201

e. Mr. Vern Lawson
Sales Manager
Mobil Chemical Company
Woodland, California 95695

f. Mr. E. W. Georgett
National Sales Manager
Union Carbide
Ind. Fabricated Products
One Cory Road
Morristown, New Jersey 07960

g. Mr. Sheldon Kritzer
Central Bag & Supply Company
2222 E. Olympic Boulevard
Los Angeles, California 90021

h. Mr. Ray Dickinson
Sales Representative
Bemis Company, Inc.
920 E. Pacific Coast Highway
Wilmington. California 90744

i. Mr. W. Brian Barry
Western Sales Manager
St. Regis Paper Company
6605 E. Flotilla Street
Los Angeles, California 90022
(Friedman Wide and Narrow, Wagner bags)

j. Chase Bag Company
4900 Corona
Los Angeles, California

2. **Paper Bags**

a. Mr. William White
Sales Manager
Westvaco Building
299 Park Avenue
New York, N.Y. 10017

b. Mr. W. Brian Barry
Western Sales Manager
St. Regis Paper Company
6605 E. Flotilla Street
Los Angeles, California 90022

c. Mr. Ray Dickinson
Sales Representative
Bemis Company, Inc.
920 E. Pacific Coast Highway
Wilmington, California 90744

d. Mr. Richard C. Martin
Western Sales Manager
International Paper Company
4635 District Boulevard
Los Angeles, California 90058

e. Mr. P. E. Strain
Product Manager
Union Camp Corp.
233 Broadway
New York, N.Y. 10007

f. Mr. Austin Byron
Manager Product Development
Hudson Paper Company
477 Madison Avenue
New York, N.Y. 10022

g. Mr. C. S. Curtiss
Manager, DisPosit Division
Gilman Paper Company
Time & Life Building
111 W. 50th Street
New York, N.Y. 10020

h. Mr. Robert Sinclair
Marketing Manager
Crown-Zellerbach Corporation
One Bush Street
San Francisco, California 94119

APPENDIX E

1. QUESTIONNAIRE 1: PRETEST

READ EACH QUESTION CAREFULLY AND CHECK THE APPROPRIATE BOX ON THE RIGHT.

		NEVER	OCCASIONALLY	SOMETIMES	FREQUENTLY	ALWAYS
1.	Do you ever see spilled refuse in the street on your collection day?	☐	☐	☐	☐	☐
2.	Do you ever see flies or ants in your trash cans?	☐	☐	☐	☐	☐
3.	Do you ever find it difficult or inconvenient to carry emptied trash cans from the curb to your storage area?	☐	☐	☐	☐	☐
4.	Does the collector ever leave small amounts of refuse in trash cans?	☐	☐	☐	☐	☐
5.	How often are your trash cans damaged by the collector?	☐	☐	☐	☐	☐
6.	Do you ever smell unpleasant odors in your trash cans?.	☐	☐	☐	☐	☐
7.	How often do you feel the appearance of your neighborhood is less attractive when trash cans are at the curb on collection day?	☐	☐	☐	☐	☐

PLEASE GIVE US YOUR COMMENTS ON THE CITY OF INGLEWOOD REFUSE COLLECTION SYSTEM.

APPENDIX E

2. QUESTIONNAIRE 2: SOLID WASTE BAG USE

1. Please check the system you have been using for the past three months:

   St. Regis Paper Bag and Holder ☐
   Mobil Plastic Bag and Holder ☐
   International Garbax Paper Bag and Holder ☐
   Plastic Liner Bags ☐
   St. Regis Paper Bag (no holder) ☐

2. Do you live in: ☐ A private residence ☐ An apartment house

3. If the system you used included a bag holder, please answer the following questions:

   a) Did you have trouble mounting the bag on the holder? ☐ Yes ☐ No
   b) Did you have difficulty placing refuse in the bag? ☐ Yes ☐ No
   c) Do you consider the holder and bag more attractive in appearance than the conventional refuse container? ☐ Yes ☐ No
   d) Did you have trouble with the holder tipping over? ☐ Yes ☐ No
   e) Did the holder lid function satisfactorily? ☐ Yes ☐ No

4. If the system you used did not include a bag holder, please answer the following questions:

   a) Did you have problems placing the liners into the cans? ☐ Yes ☐ No
   b) Did you have difficulty placing refuse into the bag? ☐ Yes ☐ No

5. Did you find it necessary to continue using conventional containers along with the bag system? ☐ Yes ☐ No If yes, please indicate briefly your reasons:

   ____
   ____
   ____
   ____

6. Did you find the bags failed: ☐ Never ☐ Occasionally ☐ Frequently

7. What was the primary cause of these failures?

Sharp objects ☐
Wet refuse ☐
Heavy refuse ☐
Animal damage ☐
Rough handling ☐
Other (please describe) ☐ ______________________________

8. Did you notice any improvement in:

Noise factor ☐ Yes ☐ No
Odor conditions ☐ Yes ☐ No
Fly problems ☐ Yes ☐ No
Spillage ☐ Yes ☐ No
Neighborhood appearance ☐ Yes ☐ No

9. Did you have problems closing the bag following use? ☐ Yes ☐ No

10. Was it difficult to carry the bags to the curb on collection day? ☐ Yes ☐ No

11. All things considered, did you like the system? ☐ Yes ☐ No

12. What did you particularly like about the system? ______________________________

____

____

____

13. What did you particularly dislike about the system? ______________________________

____

____

____

Please return the completed questionnaire to us in the enclosed envelope. Thank you for your cooperation.

APPENDIX E

3. QUESTIONNAIRE 3: SOLID WASTE BAG SYSTEM COMPARISONS

1. Check the refuse bag system used since the end of July 1969.

St. Regis Paper Bag & Holder ☐
Mobil Plastic Bag & Holder ☐
International Garbax Paper Bag & Holder ☐
Plastic Liner Bags for Cans ☐

2. Was this the same system used during the 3 month period prior to the end of July 1969?

Yes ☐ (go to Question 6)
No ☐ (go to Question 3)

3. Check the system used during the 3 month period prior to the end of July 1969.

St. Regis Paper Bag & Holder ☐
Mobil Plastic Bag & Holder ☐
International Garbux Paper Bag & Holder ☐
Plastic Liner Bags for Cans ☐

4. In comparison with the bag system used prior to the end of July 1969, rate the system you are now using as better, about the same, or worse for:

	Better	About the Same	Worse
General appearance	☐	☐	☐
Closing the filled bag	☐	☐	☐
Mounting bag on holder	☐	☐	☐
Placing refuse in bag	☐	☐	☐
Tipping of the holder	☐	☐	☐
Holder lid operation	☐	☐	☐
Frequency of bag failure	☐	☐	☐
Odor conditions	☐	☐	☐
Fly problems	☐	☐	☐
Animal attack	☐	☐	☐
Spillage	☐	☐	☐
Carrying bag to curb	☐	☐	☐
Storage of bag supplies	☐	☐	☐

5. In view of the items listed in Question 4, is the bag system in current use preferred over the one in use prior to the end of July?

Yes ☐ No ☐

6. The following questions apply to the bag system you are now using.

7. Do you live in: Private residence ☐
Apartment house ☐

8. Did you find that the bags failed:

Never ☐
Occasionally ☐
Frequently ☐

9. What was the primary cause of these failures?

Sharp objects ☐
Wet refuse ☐
Heavy refuse ☐
Animal damage ☐
Rough handling ☐

10. Did you notice any improvement in:

Collection noise Yes ☐ No ☐
Odor conditions Yes ☐ No ☐
Fly problems Yes ☐ No ☐
Spillage Yes ☐ No ☐
Neighborhood appearance Yes ☐ No ☐

11. Did you have problems closing the bag following use? Yes ☐ No ☐

12. Was it difficult to carry the bags to the curb? Yes ☐ No ☐

13. All things considered, did you like the system? Yes ☐ No ☐

14. If there was anything you particularly liked about the system, please comment:

____

____

____

15. If there was anything you particularly disliked about the system, please comment:

____

____

____

16. If the bag system you are now using includes a special bag holder stand, please answer the following:

a) Did you have trouble mounting the bag on the holder? Yes ☐ No ☐

b) Did you have difficulty placing refuse in the bag? Yes ☐ No ☐

c) Do you consider the holder and bag more attractive in appearance than the conventional refuse container? Yes ☐ No ☐

d) Do you have trouble with the holder tipping over? Yes ☐ No ☐

e) Does the holder lid function satisfactorily? Yes ☐ No ☐

17. If the system you used did not include a bag holder, please answer the following:

a) Did you have difficulty placing refuse into the bag? Yes ☐ No ☐

18. Please indicate any special comments you have regarding the test.

____

____

____

____

____

____

____

Please return the completed questionnaire as soon as possible in the enclosed envelope.

APPENDIX E

4. QUESTIONNAIRE 4: BRIARWOOD CONDOMINIUM - SOLID WASTE BAG USE

Dear Citizen of Briarwood:

For the past six months you have been involved in making a study of a new method of refuse collection and storage system with the City of Inglewood which has been sponsored by the United States Public Health Service.

To help us evaluate this system, we would appreciate it if you would take a few moments to answer the following questions.

1. Did you have trouble mounting bag? Yes ☐ No ☐
2. Did you have difficulty placing refuse in the bag? Yes ☐ No ☐
3. Do you consider the holder and bag more attractive than the conventional refuse container? Yes ☐ No ☐
4. Did you have trouble with the holder tipping over? Yes ☐ No ☐
5. Did the holder lid function satisfactorily? Yes ☐ No ☐
6. Did the bags fail often? Yes ☐ No ☐
7. What was the primary cause of the failures?

   Sharp objects ________ Animal damage ________
   Wet refuse ________ Rough handling ________
   Heavy refuse ________

8. Did you notice any improvement in:

   Noise factor Yes ☐ No ☐ Fly problem Yes ☐ No ☐
   Odor conditions Yes ☐ No ☐ Spillage Yes ☐ No ☐
   Neighborhood appearance Yes ☐ No ☐

9. Did you have problems closing the bag? Yes ☐ No ☐
10. Was there a problem in storage of bags before use? Yes ☐ No ☐
11. All things considered, did you like the system? Yes ☐ No ☐

12. Please make any comments about the system that will give us your opinion of the system.

____

____

____

____

____

____

APPENDIX E

5. QUESTIONNAIRE 5: BAG SYSTEM EVALUATION

1. Please check different systems used by you during the past 1-1/2 years.

St. Regis Paper Bag & Holder ☐
International Paper Bag & Holder ☐
Mobil Plastic Bag & Holder ☐
Mobil Plastic Liners for Barrels ☐
Plastic Bags with Drawstrings ☐

2. Of the different types of bags that you used, which did you like best?

____

3. Did you notice any improvement in:

Noise Factor Yes ☐ No ☐
Neighborhood Appearance Yes ☐ No ☐
Spillage on Parkway or Street Yes ☐ No ☐

4. Did you have trouble installing liner into barrel? Yes ☐ No ☐

5. Did you have trouble removing liner from barrel? Yes ☐ No ☐

Item	Importance			
	None	Very little	Moderate	Great
Frequency of bag failure				
Ease of closing filled bag				
Ease of mounting bag on holder				
Ease of filling bag				
Ease of operation of holder lid				
Odor conditions				
Ease of storage of bag supply				
Ease of carrying filled bag				
Frequency of spillage				
Frequency and extent of animal damage				

All things considered, did you like the system? Yes ☐ No ☐

Please make any comments about the system that might help us to make an evaluation.

____

____

____

Please return to Harry Frisby, Sanitation Superintendent, City of Inglewood. An envelope has been enclosed for your convenience.

APPENDIX E

6. LANDFILL OPERATOR QUESTIONNAIRE

Compared to normal residential refuse, how would you evaluate working bagged refuse in the following operations:

		Better	Same	Worse	
		1 2 3	4 5 6 7	8 9 10	
a.	Pushing	☐	☐	☐	________
b.	Spreading	☐	☐	☐	________
c.	Compacting	☐	☐	☐	________

How would you rate bagged refuse compared to normal residential refuse for the following:

		Better	Same	Worse	
		1 2 3	4 5 6 7	8 9 10	
a.	Blowing refuse	☐	☐	☐	________
b.	Odors	☐	☐	☐	________
c.	Dust produced in working	☐	☐	☐	________

Comments: ____

____

____

____

____

____

____

APPENDIX E

7. NATIONWIDE SOLID WASTE BAG USE QUESTIONNAIRE

1. City_____________________ State__________________ Population______________
2. Do City regulations permit use of plastic and/or paper bags as refuse containers? _____Yes; _____No. Please provide a copy of City Regulations.
3. Please estimate current (1970) percentage of households using plastic and/or paper bags as refuse containers. _____0-5%; _____6-20%; _____21-40%; _____41-60%; _____61-80%; _____81-95%; _____96-100%.
4. Of total number of refuse bags used in City as refuse containers, about _____% are plastic and _____% are paper.
5. Does City plan to use, or permit householders to use, disposable bags for refuse containers in the future? _____Yes; _____No. If Yes, will bags be _____plastic only; _____or both?
6. If now used, how do householders obtain disposable bags? (Please describe)

   ____.
7. What size bag is now provided? _____gallons.
8. Householders pay about _____¢ per paper bag; _____¢ per plastic bag.
9. Does City now incur costs of bag distribution to residents? _____Yes; _____No. If Yes, what is method of distribution and approximate cost per bag distributed?

   ____
10. Please rate, in your opinion, the householder's reaction to the use of disposable bags in your City. Circle one number from 1 to 10.

1 2 3	4 5 6 7	8 9 10
very unsatisfactory	satisfactory	very satisfactory

11. Please indicate what problems, if any, the City has experienced in the collection and/or final disposal of refuse bags, and whether the difficulty involved paper or plastic bags.____

    ____
12. If plastic bags are now used or planned for future use, do you personally favor their use _____as a liner; _____with a holder; and what minimum thickness? _____mil.
13. In your personal judgment, which type of bag is superior? _____plastic; _____paper.

14. Do you know of any private scavenger firms or other cities who supply plastic and/or paper bags to their customers? _____ Yes; _____ No. If yes, please write their names and addresses on back of this questionnaire.

15. Has City conducted studies to determine refuse collection cost savings resulting from use of plastic and/or paper bags? _____ Yes; _____ No. If Yes, please send copy of study results.

16. OPTIONAL: Your name and title_______________________________________

PLEASE USE REVERSE SIDE FOR ADDITIONAL COMMENTS

APPENDIX E

8. BIN LINER QUESTIONNAIRE

Name of Business ____________________

1. Did you notice any improvement in:

a.	Fly Problems	Yes ☐	No ☐
b.	Odors	Yes ☐	No ☐
c.	Bin Cleanliness	Yes ☐	No ☐

2. Did you have trouble installing the liner into the bin? Yes ☐ No ☐

   If Yes, please explain: ____________________

   ____

   ____

3. Do you clean your bin regularly? Yes ☐ No ☐

4. Has the use of liners reduced the frequency of need for cleaning of bin? Yes ☐ No ☐

5. All things considered, did you like the system? Yes ☐ No ☐

6. Do you feel the City of Inglewood should encourage the use of bin liners for business locations that have food waste? Yes ☐ No ☐

Comments: ____________________

____

____

____

We wish to thank you for your cooperation in this study and if you have any questions, please call Harry M. Frisby, Sanitation Superintendent, 674-7111, Ext. 361, City of Inglewood.

APPENDIX F

LABORATORY PROCEDURE FOR ANALYSIS OF MICROBIOLOGICAL DUST TESTS

Bacterial sample plates 100 mm in diameter containing brain heart infusion agar were exposed for 10 seconds during collection of domestic solid waste. The exposed agar plates were incubated at room temperature (75 ±4°F) for several days. Microbial colonies developing on these plates during incubation were counted at 24-hour intervals. A distinction was made between bacteria and fungi on the basis of their colonial morphology.

After 48 hours of incubation, the most abundant types of colonies of bacteria were selected and streaked on blood agar plates. The plates were incubated at room temperature and examined after 24 hours for bacterial growth and hemolysis of red blood cells around the growing colonies. All the bacteria grown on blood agar plates were stained for gram's stain and viewed under a microscope at a magnification of 970 X.

On the basis of colonial morphology, the reaction to gram's stain, and cellular morphology, the generic bacteria were tentatively identified.

Predominant fungi colonies were identified on the basis of their fruiting structures. For this purpose a portion of the colony was mounted on a microscopic slide and teased onto a drop of lactophenol cotton blue fluid, covered with a cover-glass, and pressed gently. The slide was then examined under a microscope (500 X magnification). When necessary, fungi were subcultured on Sabourand's dextrose agar and treated as above for proper identification.

APPENDIX G

BIBLIOGRAPHY ON DUST STUDIES

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APPENDIX H

RESPONSE SUMMARY: QUESTIONNAIRES 2 AND 3

The following tables list the detailed responses to each questionnaire. Table H1 and H3 are expressed in number of responses, and Tables H2 and H4 are given in percentage of responses.

TABLE H1

SUMMARY OF RESPONSES TO QUESTIONNAIRE 2

	Mobil[a] & Holder (114)[d]		St. Regis[b] & Holder (154)		International[b] & Holder (114)		Friedman Wide Can Liner[c] (121)		St. Regis[b] No Holder (33)		Total (536)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Improvements												
Holder and bag more attractive than conventional solid waste container	88	23	131	21	87	18	N.A.[e]	N.A.	N.A.	N.A.	306	62
Neighborhood appearance	87	13	123	19	87	12	103	9	27	3	427	56
Collection Noise	76	26	102	33	70	20	78	25	21	5	347	109
Odor Conditions	66	33	100	35	63	37	80	25	16	8	325	138
Fly problem	55	38	101	36	66	33	72	31	17	9	311	147
Spillage problem	67	33	97	40	57	36	90	16	15	11	326	136
Difficulties												
Mounting bag or liner	36	79	21	133	6	105	8	108	5	16	75	441
Placing solid waste in bag	45	69	17	136	15	87	8	108	8	21	93	421
Closing bag	30	76	38	103	26	78	25	79	12	20	131	356
Carrying bags to curb	4	97	14	129	12	90	20	94	4	27	54	437
Necessary to continue to use cans with bags	57	24	46	65	42	38	47	67	13	15	205	209
Did holder lid function satisfactorily	56	58	145	5	103	7	N.A.	N.A.	N.A.	N.A.	70	304
Tipping over of holder	7	105	7	142	8	104	N.A.	N.A.	N.A.	N.A.	22	351

Continued . . .

TABLE H1 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 2

<table>
<tr><th rowspan="2"></th><th colspan="2">Mobil[a]
& Holder
(114)[d]</th><th colspan="2">St. Regis[b]
& Holder
(154)</th><th colspan="2">International[b]
& Holder
(114)</th><th colspan="2">Friedman Wide
Can Liner[c]
(121)</th><th colspan="2">St. Regis[b]
No Holder
(33)</th><th colspan="2">Total

(536)</th></tr>
<tr><th>Yes</th><th>No</th><th>Yes</th><th>No</th><th>Yes</th><th>No</th><th>Yes</th><th>No</th><th>Yes</th><th>No</th><th>Yes</th><th>No</th></tr>
<tr><td>Bags failed never</td><td colspan="2">30</td><td colspan="2">79</td><td colspan="2">55</td><td colspan="2">61</td><td colspan="2">15</td><td colspan="2">240</td></tr>
<tr><td>Bags failed occasionally</td><td colspan="2">57</td><td colspan="2">53</td><td colspan="2">44</td><td colspan="2">53</td><td colspan="2">15</td><td colspan="2">222</td></tr>
<tr><td>Bags failed frequently</td><td colspan="2">16</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">3</td><td colspan="2">3</td><td colspan="2">39</td></tr>
<tr><td>Primary causes of failure</td><td colspan="12"></td></tr>
<tr><td>Sharp objects</td><td colspan="2">64</td><td colspan="2">19</td><td colspan="2">26</td><td colspan="2">52</td><td colspan="2">9</td><td colspan="2">172</td></tr>
<tr><td>Wet solid waste</td><td colspan="2">7</td><td colspan="2">19</td><td colspan="2">29</td><td colspan="2">5</td><td colspan="2">7</td><td colspan="2">67</td></tr>
<tr><td>Heavy solid waste</td><td colspan="2">27</td><td colspan="2">6</td><td colspan="2">12</td><td colspan="2">17</td><td colspan="2">6</td><td colspan="2">68</td></tr>
<tr><td>Animal damage</td><td colspan="2">20</td><td colspan="2">33</td><td colspan="2">21</td><td colspan="2">10</td><td colspan="2">7</td><td colspan="2">91</td></tr>
<tr><td>Rough handling</td><td colspan="2">4</td><td colspan="2">1</td><td colspan="2">0</td><td colspan="2">4</td><td colspan="2">1</td><td colspan="2">10</td></tr>
<tr><td>Did you like the system</td><td>70</td><td>24</td><td>118</td><td>22</td><td>82</td><td>16</td><td>106</td><td>7</td><td>26</td><td>4</td><td>402</td><td>73</td></tr>
</table>

[a] Mobil Keepaway (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] Polyethylene (3.0 mil).
[d] Figures in parentheses give number of questionnaires returned.
[e] Not applicable.

TABLE H2

SUMMARY OF RESPONSES TO QUESTIONNAIRE 2 (Expressed in Percentages)

	Mobil[a] & Holder			St. Regis[b] & Holder			International[b] & Holder		
Improvements	Yes	No	N.R.[d]	Yes	No	N.R.	Yes	No	N.R.
Holder and bag more attractive than conventional solid waste container	77.2	20.2	2.6	85.1	13.6	1.3	76.3	15.8	7.9
Neighborhood appearance	76.3	11.4	12.3	80.0	12.3	7.7	76.3	10.5	13.2
Collection noise	66.7	22.8	10.5	66.2	21.4	12.4	61.4	17.5	21.1
Odor conditions	57.9	28.9	13.2	64.9	22.7	12.4	55.3	32.5	12.2
Fly problem	48.2	33.3	18.5	65.6	23.4	11.0	57.9	28.9	13.2
Spillage problem	58.8	28.9	12.3	63.0	26.0	11.0	50.0	31.6	18.4
Difficulties									
Mounting bags or liner	30.7	69.3	0	13.6	86.4	0	5.3	92.1	2.6
Placing solid waste in bag	39.5	60.5	0	11.0	88.3	0.7	13.2	76.3	10.5
Closing bag	26.3	66.7	7.0	24.7	66.9	8.4	22.8	68.4	8.8
Carrying bags to curb	3.5	85.1	11.4	9.1	83.8	7.1	10.5	78.9	10.6
Necessary to continue to use cans with bags	50.0	21.1	28.9	29.9	42.2	27.9	36.8	33.3	29.9
Did holder lid function satisfactorily	49.1	50.9	0	94.2	3.2	2.6	90.4	6.1	3.5
Tipping over of holder	6.1	92.1	1.8	4.5	92.2	3.3	7.0	91.2	1.8
Bags failed never		26.3			51.3			48.2	
Bags failed occasionally		50.0			34.4			38.6	
Bags failed frequently		14.0			5.2			7.9	
Primary causes of failure[e]									
Sharp objects		52.5			24.4			20.5	
Wet solid waste		5.7			24.4			33.0	
Heavy solid waste		22.1			7.7			13.6	
Animal damage		16.4			42.3			23.9	
Rough handling		3.3			1.2				
Did you like the system	61.4	21.1	17.5	76.6	14.3	9.1	71.9	14.0	14.1

Continued . . .

TABLE H2 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 2 (Expressed in Percentages)

	Friedman Wide[c] Can Liner			St. Regis,[b] No Holder			Total		
Improvements	Yes	No	N.R.	Yes	No	N.R.	Yes	No	N.R.
Holder and bag more attractive than conventional solid waste container	N.A.[f]	N.A.	N.A.	N.A.	N.A.	N.A.	80.1	16.2	3.7
Neighborhood appearance	85.1	7.4	7.5	81.8	9.1	9.1	79.7	10.4	8.7
Collection noise	64.5	20.7	14.8	63.6	15.2	21.2	64.7	20.3	15.0
Odor conditions	66.1	20.7	13.2	48.5	24.2	27.3	60.6	25.7	13.7
Fly problem	59.5	25.6	14.9	51.5	27.3	21.2	59.0	27.4	14.6
Spillage problem	74.4	13.2	12.4	45.5	33.3	21.2	60.8	25.4	13.8
Difficulties									
Mounting bags or liner	6.6	89.3	4.1	15.2	48.5	39.3	14.0	82.3	3.7
Placing solid waste in bag	6.6	89.3	4.1	24.2	63.6	12.2	17.4	78.5	4.1
Closing bag	20.7	65.3	14.0	36.4	60.6	3.0	24.4	66.4	9.2
Carrying bags to curb	10.5	77.7	5.8	12.1	81.8	6.1	10.1	81.5	8.4
Necessary to continue to use cans with bags	38.8	55.4	5.8	39.3	45.4	15.2	38.2	39.0	22.8
Did holder lid function satisfactorily	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	18.3	79.6	2.1
Tipping over of holder	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	5.8	91.9	2.3
Bags failed never		50.4			45.5			44.8	
Bags failed occasionally		43.8			45.5			41.4	
Bags failed frequently		2.5			9.1			7.3	
Primary causes of failure[e]									
Sharp objects		59.1			30.0			12.2	
Wet solid waste		5.7			23.3			16.4	
Heavy solid waste		19.3			20.0			16.7	
Animal damage		11.4			23.3			22.3	
Rough handling		4.5			3.4			2.5	
Did you like the system	87.6	5.8	6.6	78.8	12.1	9.1	75.0	13.6	11.4

Continued . . .

TABLE H2 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 2
(Expressed in Percentages)

[a] Mobil Keepaway (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] Polyethylene (3.0 mil).
[d] No response.
[e] Percentages are based upon total number of failure types reported.
[f] Not applicable.

TABLE H3

SUMMARY OF RESPONSES TO QUESTIONNAIRE 3

	Mobil[a] & Holder (98)[d]		St. Regis[b] & Holder (102)		International[b] & Holder (86)		Wagner Can Liner[c] (124)		St. Regis[b] No Holder (3)		Total (413)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Improvements												
Holder and bag more attractive than conventional solid waste container	70	23	80	15	64	15	N.A.[e]	N.A.	N.A.	N.A.	214	53
Neighborhood appearance	75	19	90	10	67	18	103	16	2	0	337	63
Collection noise	67	22	85	11	60	23	90	28	2	0	304	84
Odor conditions	54	31	68	23	52	25	75	37	1	1	260	117
Fly problem	53	36	66	24	49	31	73	41	1	1	242	133
Spillage problem	57	28	69	20	54	23	83	30	1	1	264	102
Difficulties												
Mounting bag	41	52	21	77	16	65	N.A.	N.A.	N.A.	N.A.	78	194
Placing solid waste in bag	52	42	11	87	18	63	14	72	0	0	95	264
Closing bag	41	58	27	75	34	50	32	90	1	1	135	274
Carrying bags to curb	6	90	9	92	14	72	23	96	1	2	53	352
Did holder lid function satisfactorily	36	55	86	12	71	9	N.A.	N.A.	N.A.	N.A.	193	76
Holder tipping over	25	67	12	86	9	72	N.A.	N.A.	N.A.	N.A.	46	225

Continued . . .

TABLE H3 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 3

		Mobil[a] & Holder (98)[d]		St. Regis[b] & Holder (102)		International[b] & Holder (86)		Wagner Can Liner[c] (124)		St. Regis[b] No Holder (3)		Total (413)	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	never	25		48		40		58		1		172	
Bags failed	occasionally	53		48		29		59		3		192	
	frequently	16		6		5		6		0		33	
Primary causes of failure													
Sharp objects		58		33		22		59		0		172	
Wet solid waste		6		23		19		3		1		52	
Heavy solid waste		18		5		3		10		0		36	
Animal damage		26		26		25		20		0		97	
Rough handling		5		0		2		7		1		15	
Did you like the system		67	29	92	10	69	15	106	13	2	1	336	68

[a] Mobil Keepaway (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] Polyethylene (3.5 mil).
[d] Figures in parentheses give number of questionnaires returned.
[e] Not applicable.

TABLE H4

SUMMARY OF RESPONSES TO QUESTIONNAIRE 3 (Expressed in Percentages)

	Mobil[a] & Holder			St. Regis[b] & Holder			International[b] & Holder		
	Yes	No	N.R.[d]	Yes	No	N.R.	Yes	No	N.R.
Improvements									
Holder and bag more attractive than conventional solid waste container	71.4	23.5	5.1	78.4	14.7	6.9	74.4	17.4	8.1
Neighborhood appearance	76.5	19.4	4.1	88.2	9.8	2.0	77.9	20.9	1.2
Collection noise	68.4	22.4	9.2	83.3	10.8	5.9	69.8	26.7	3.5
Odor conditions	55.1	31.6	13.3	66.7	22.5	10.8	60.5	29.1	10.4
Fly problem	54.1	36.7	9.2	64.7	23.5	11.8	57.0	36.0	7.0
Spillage problem	58.2	28.6	13.2	67.6	19.6	12.8	67.8	26.7	10.5
Difficulties									
Mounting bag	41.8	53.1	5.1	20.6	75.5	3.9	18.6	75.6	5.8
Placing solid waste in bag	53.1	42.9	4.0	10.8	85.3	3.9	20.9	73.3	5.8
Closing bag	41.8	59.2	0	26.5	73.5	0	39.5	58.1	2.4
Carrying bags to curb	6.1	91.8	2.1	8.8	90.2	1.0	16.3	83.7	0
Did holder lid function satisfactorily	35.3	53.9	10.8	87.8	12.2	0	82.6	10.5	6.9
Tipping over of holder	25.5	68.4	6.1	11.8	84.3	3.9	10.5	83.7	5.8
never		25.5			47.1			46.5	
Bags failed occasionally		54.1			47.1			33.7	
frequently		16.3			5.9			5.8	
Primary causes of failure[e]									
Sharp objects		51.3			37.9			31.0	
Wet solid waste		5.3			26.5			26.8	
Heavy solid waste		15.9			5.7			4.2	
Animal damage		25.1			29.9			35.2	
Rough handling		4.4						2.8	
Did you like the system	68.4	29.6	2.0	90.2	9.8	0	80.2	17.4	2.4

Continued . . .

TABLE H4 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 3 (Expressed in Percentages)

	Wagner Can Liner[c]			St. Regis,[b] No Holder			Total		
	Yes	No	N.R.	Yes	No	N.R.	Yes	No	N.R.
Improvements									
Holder and bag more attractive than contentional solid waste container	N.A.[f]	N.A.	N.A.	N.A.	N.A.	N.A.	74.8	18.4	6.7
Neighborhood appearance	83.1	12.9	4.0	66.7	0	33.3	81.6	15.3	3.1
Collection noise	72.6	22.6	4.8	66.7	0	33.3	73.6	20.3	6.1
Odor conditions	60.5	29.8	9.7	33.3	33.3	33.4	63.0	28.3	8.7
Fly problem	58.9	33.1	8.0	33.3	33.3	33.4	58.6	32.2	9.2
Spillage problem	66.9	24.2	8.9	33.3	33.3	33.4	63.9	24.7	11.4
Difficulties									
Mounting bag	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	27.3	67.8	4.9
Placing solid waste in bag	11.3	58.1	30.6	0	0	0	23.3	64.7	12.0
Closing bag	25.8	72.6	1.6	33.3	33.3	33.4	32.7	66.3	1.0
Carrying bags to curb	18.5	77.4	4.1	33.3	66.7	0	12.8	85.2	2.0
Did holder lid function satisfactorily	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.5	26.6	5.9
Tipping over of holder	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	16.1	78.7	5.2
never		46.8			33.3			41.6	
Bags failed occasionally		47.6			100.0			46.5	
frequently		4.8			0			8.0	
Primary causes of failure[e]									
Sharp objects		59.6			0			46.2	
Wet solid waste		3.0			50.0			14.0	
Heavy solid waste		10.1			0			9.7	
Animal damage		20.2			0			26.1	
Rough handling		7.1			50.0			4.0	
Did you like the system	85.5	10.5	4.0	66.7	33.3	0	81.4	16.5	2.1

Continued . . .

TABLE H4 (Continued)

SUMMARY OF RESPONSES TO QUESTIONNAIRE 3
(Expressed in Percentages)

[a] Mobil Keepaway (2.5 mil) polyethylene bag.
[b] Paper bag.
[c] Polyethylene (3.5 mil).
[d] No response.
[e] Percentages are based upon total number of failure types reported.
[f] Not applicable.

APPENDIX I

Mathematical Model Description

A. Model Inputs

1. General: A simplified model was used to simulate the time required for the collection of refuse. The purpose of the model was to enable projections of refuse collection system performance for alternative crew sizes, collection methodologies, truck sizes, haul distances, and labor and equipment costs. The following factors which affect the efficiency of collection were included in the model:

   a. Mean quantity of refuse per collection stop.

   b. Driving time between the route and the disposal site.

   c. Mean collection time at each collection stop and travel time to the next stop.

   d. Total non-productive time including: travel time between the yard and the route and between the disposal site and the yard; relief, lunch, and dispatch time; and incidential time losses resulting from road conditions, equipment breakdown, etc.

   e. Mean disposal time per load at the disposal site.

2. Assumptions and Data: The basic model assumptions and data inputs were as follows:

   a. Collection plus travel time per stop in minutes from Table 66:

	CS=1	CS=2	CS=3
Bag routes: t=	0.58	0.53	0.41
Can routes: t=	0.74	0.69	0.58

Collection times for two-and three-man crews collecting bags was derived from Methods-Time-Measurements (MTM) analyses as described in the One-Man Report[2] as follows:

> Adjusted MTM values from the One-Man Report Figures 40 to 42 page 96-98, correlated well with field data. The MTM unadjusted value for 3 cans on Figure 29 (p. 68) was plotted on Figures 40 to 42. The percentage increases in the latter values, calculated to obtain the field values for 3 cans as shown on Figures 40 to 42, were:
>
> CS = 1 : 0.5 to 0.62 min.; 25%
> CS = 2 : 0.33 to 0.55; 66%
> CS = 3 : 0.29 to 0.45; 55%

Applying these percentages to the unadjusted MTM times for disposable items given in Figure 30 (p. 69), the times for 2- and 3-man crews were obtained; adding a constant travel time between stops of 0.13 minutes the times were calculated as follows:

$CS = 2: t = 0.13 + 0.24 + (.66)(.24) = 0.40 + 0.13 = 0.53$ min.
$CS = 3: t = 0.13 + 0.18 + (.55)(.18) = 0.28 + 0.13 = 0.41$ min.

Collection times for 2- and 3-man crews on can roures were derived as follows:

The 0.74 min for 1-man can collection plus travel to the next stop when reduced by the 0.13 min travel time (0.61 min) is identical to the 0.62 min given on page 21 of the One-Man Report.[2] Times for 2- and 3-man crews were considered similar also, and when travel time between stops was added the 2- and 3-man crew times for can collection were derived.

$CS = 2: 0.558 + 0.13 = 0.69$ min.
$CS = 3: 0.454 + 0.13 = 0.58$ min.

b. Minimum partial loads to be collected were set at: 1/8, 1/4 and 1/2.

c. Standard work day of 8 hours (480 min day), with a maximum allowable overtime of 30 min (510 min/day).

d. Crew members are paid for a minimum of 8 hours per day at $4.80 per hour; if they finish early they are relieved.

e. Time worked beyond 8 hours is overtime at 1.5 times the normal rate.

f. Collection truck sizes and costs used in the model were:

truck volume, cu yd: 20, 25, 32, 35, 40
truck costs (Table 67), $/min: 0.073, 0.078, 0.085, 0.093, 0.095.

g. Refuse quantities per stop: $Q = 50, 60, 70$ lb.

h. Non-productive time; $K = 100, 75, 50$ min.

i. One-way drive time, route to disposal $B = 50, 30, 10$.

j. Mean density of waste in the collection vehicle after compaction: 550 lb per cu yd.

3. Symbols

B	One way average driving time between the route and the disposal site (min)
D	The mean disposal time (min/load)
d	Mean density of waste in the vehicle (lb/cu yd)
K	The total non-productive time (min)
PL	Partial load (fraction)
SPL	Number of services for a full or partial load
TPL	Time to collect one vehicle load (min)
X	Total time to complete a days work (min)
V	Vehicle volumetric capacity
t	Time necessary for one service (min)

B. Model Calculations

The model calculations are made as follows:

1. Calculate the number of services for a full load (SPL):

$$SPL = \frac{V*d}{Q}$$

2. The time to collect one load (TPL):

$$TPL = SPL * t$$

The total time to complete one trip is found from:

3. $X(I) = TPL + K + B + D$
4. If $X(I) < 510$ min check to see if $X(I) \geq 480$ min.
5. If $X(I) \geq 480$ min, only one trip is made for the day. Complete Step 16.
6. If $X(I) \geq 510$ min, a partial load is collected for the day:

$PL = (510 - X(I) + TPL) / TPL$

7. set $X(I) = 510$ min where load = PL
8. If $X(I) < 480$ min, the next trip (travel time) XX is calculated without collection by:
9. $XX = X(I) + 2*B + D$

10. If XX $\geqq$ 510 min the trips are finished for the day. Go to step 16.

11. If XX < 510 min. the partial load that can be collected in the remaining time is calculated.

$$PL = (510 - XX)/TPL$$

A minimum allowable load may be specified, such as 1/8, 1/4, 1/2.

12. If PL < PL min, then no more trips are made. Go to step 16.

13. If PL $\geqq$ PL min, then make another trip and calculate the load from Step 6.

14. If PL < 1.0, set X = 510 min and collect a partial load. Go to step 16.

15. If PL $\geqq$ 1.0, calculate the number of trips for the day until the time constraints are satisfied: X = XX + TPL and repeat from step 5.

16. When the trips for a day are finished and totalled, then the following are calculated:

(1) load size tons; (2) number of services; (3) man minutes per ton for the crew size; (4) manpower costs at straight time and overtime if used; (5) labor cost per ton; (6) vehicle cost per ton; (7) total cost per ton; and (8) cost per service.

C. Model Simulations and Behavior

Several model simulation runs were made under varying collection system conditions of partial loads, quantity of waste per stop, collection truck volumes, non-productive time, and one way drive time from route to disposal.

The basic equation of the model given on page 55 is linear; the behavior of the model when simulations are run under varying system conditions, however, is nonlinear. The nature of the constraints on daily work time and their interaction with different vehicle capacities and crew sizes results in nonlinear solution lines (see Figures 50-60 in text) when variables are plotted as a function of truck volume. This occurs because the daily work time constraint causes the solution to behave as a modified step - function. The actual time a given vehicle/crew spends on the route and in transit is used to determine collection costs; the amount of time a vehicle/crew spends on a route may, therefore, vary from 510 minutes to less than 480 minutes. Collection costs include overhead for differences in work times, numbers of services and trips per day. The non-productive time per day is assumed constant and is added only once in the model solution regardless of the number of trips completed during the day.

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